U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-298 108

Research Highlights 1978

Delamer, Inc, Cupertino, CA

Prepared for

Environmental Protection Agency, Washington, DC Office of Research and Development

Dec 78

foreword

Scientists have certain natural enemies. Ignorance is one. Prejudice and mythology are others. Where there is a gap in our knowledge, unfortunately, there is all too often someone ready to fill it with half-truths and myths. Thus filled, the gap is no longer the unknown waiting to be explored — it has become a prejudice which is often hotly defended in the face of contrary truths.

During 1978, we in EPA's Office of Research and Development challenged several popular myths head-on. For example, it has become popular of late to look upon environmental pollution controls as a major cause of inflation. Armed with half-truths concerning the potential costs of assuring that our citizens are protected against unacceptable doses of various poisons, a small band of 'true believers' is attacking many of our environment quality standards. What such attacks fail to recognize, however, is the immense potential benefit, savings, and deflationary impact which can be realized from a cleaner environment. Our study of the health care and property value costs of air pollution in the Los Angeles area (p.67), for example, quantifies some of the costs of air pollution and shows how these costs may be far greater than the costs of cleaning up that pollution.

Another of our 1978 accomplishments was the testing of alternative methods of treating wastewater (p.20) which are not only effective, but also less expensive and less energy-intensive. In our efforts to reduce air pollution, we have designed an oil furnace for homes (p.45) which will not only meet or exceed our emissions goals, but will do so at an 18 percent savings in fuel use!

Another myth challenged by our research efforts in 1978 is the feeling that "everything is poisonous or causes cancer anyway, so why care?" This is a very powerful myth that spawns a sense of helplessness and inaction. It is also dead wrong. One series of tests sponsored by the National Cancer Institute, for example, showed that only 11 out of 120 industrial chemicals tested caused cancer when administered to test animals in large doses. In 1978, we took significant strides toward improving, and making less expensive, methods to determine whether or not a substance is safe. Our 'bugwatcher' (p.2) techniques proved able to detect, in a very short time, behavioral changes in test animals exposed to various substances. Such changes are often early warnings of toxicity. Another experiment (p.4) provided a rapid means of determining how much a substance might bioaccumulate (concentrate) as it is passed up the food chain eventually to become food for humans. Yet another of our studies (p.21) indicates that wastewater treatment plants are not hazardous to the health of nearby residents.

While such research may help to improve the healthfulness of the environment, other projects save lives in a far more direct fashion. The 'rumble reader' (p.25) for example, was developed by ORD to test the stability of hazardous materials storage ponds. It is now receiving far more widespread use in testing the stability of some of the nation's earth dams to help avoid the kinds of tragedies caused by dam failures in the past.

At the same time as we seek knowledge in these and many other areas, we provide direct support to the regulatory offices of the EPA. For example, in a massive effort which involved four of our laboratories during much of the year, ORD provided guidelines for water quality criteria to protect aquatic life for 65 different chemicals. In addition, one of our health laboratories developed, under a crash effort, health assessments for 20 of the 65 chemicals.

We are proud of our research program, and of the benefits that it provides. As you read through this, the second of our Research Highlights reports, I think you'll see why.

Stephen J. Gage

Stephen J. Gage

Assistant Administrator
Research and Development

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. 600/9-78-040	2.	3. RECIPIENT'S ACCESSION NO. PB298108
4. TITLE AND SUBTITLE Research Highlights 1978		5. REPORT DATE December 1978
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Edited by David Myers		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Delamer, Inc. Cupertino, CA the Environmental Protection Agency's		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Office of Research and Development U.S. EPA Washington, D.C. 20460		13. TYPE OF REPORT AND PERIOD COVERED Annual - 1978
		14. SPONSORING AGENCY CODE EPA/600/00

15. SUPPLEMENTARY NOTES
This is the second highlights of the Office of Research and Development. Research Highlights 1977 is available as EPA-600/9-77-044 (NTIS PB 281305).

16. ABSTRACT

This collection of research project highlights decribes some of the most interesting, fruitful, and far-reaching results produced by EPA's Office of Research and Development (ORD) during 1978. In some cases the highlighted projects are culminations of either many years of research or the integration of separate but related studies; in other cases the projects were initiated, conducted and completed in one year. These latter projects are generally representative of ORD's ability to react to emergencies, to meet requests for assistance, and to handle other situations that demand a rapid, intensive response. Our research is carried out by EPA scientists in ORD laboratories, by researchers employed by other federal agencies and funded by EPA, or by grantees and contractors supervised by ORD scientific management personnel. All of our research seeks to apply the most advanced scientific techniques and, where relevant, sensitive and humane treatment of test animals. The studies are in all parts of the nation, from an air pollution monitoring project in St. Louis, to collection of pollution-ingesting mollusks along the New England coast to samples of drinking water supplies from Seattle and other major cities.

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution, Research management, Potable water, sulfur sludge, nitrogen oxides, air pollution, Economics, Mines, Diesels, cancer	Annual Report, Earthen dams, Bioaccumulation,	13 B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 77
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE PCA05/MF-A01

EPA Form 2220-1 (9-73)

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For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Stock Number 055-000-00174-0

introduction

1978 research highlights

This collection of research project highlights describes some of the most interesting, fruitful, and far-reaching results produced by EPA's Office of Research and Development (ORD) during 1978. In some cases the highlighted projects are culminations of either many years of research or the integration of separate but related studies; in other cases the projects were initiated, conducted and completed in one year. These latter projects are generally representative of ORD's ability to react to emergencies, to meet requests for assistance, and to handle other situations that demand a rapid, intensive response.

Our main funcion at ORD is to provide EPA with a sound scientific base for the promulgation, enforcement, and review of environmental standards and regulations. The primary research results consist of information to characterize pollution threats, define the health and ecological dangers from polluting sources, and when possible to develop, test, and evaluate appropriate means to control pollution.

Inherent in our research is an appreciation and careful consideration of the costs, in terms of capital outlay or of quality of life degradation, which may result from controlling or not controlling identified harmful pollution. A specific example of this perspective is in the chapter entitled "Air Pollution Index" that documents results of a study on the balance of risks and benefits of air pollution control.

Part of our research program is also the anticipation of potential pollution threats, particularly new types of pollution that may result from our nation's shifting energy posture to meet the looming energy crisis. Diesel cars with their high fuel economy may capture significant shares of the American automobile market but may, at the same time, contribute substantial amounts of hazardous pollutants to urban air. Our chapter on "Diesels" discusses our efforts to determine the hazards. Similarly, oil shale may become a key domestic energy supply, but it too may produce new types and concentrations of pollution. Our "Oil Shale" chapter describes how EPA is helping the oil shale industry to "design-in" technology and management practices adequate to meet future regulations. The philosophy applied in both of these cases is representative of many of our other projects, that is, that scientific knowledge about a pollution source before it becomes a problem will enable costly control retrofits to be avoided. Hence, we work to keep the environment clean at the lowest cost.

Our research is carried out by EPA scientists in ORD laboratories, by researchers employed by other federal agencies and funded by EPA, or by grantees and contractors supervised by ORD scientific management personnel. All of our research seeks to apply the most advanced scientific techniques and, where relevant, sensitive and humane treatment of test animals. The studies are in all parts of the nation, from an air pollution monitoring project in St. Louis, to collection of pollution-ingesting mollusks along the New England coast to samples of drinking water supplies from Seattle and other major cities. In many of these projects we have collaborated with local research institutions and, in some instances, have coordinated with interested individuals. We intend to continue those associations and to forge new ones. Inside of the back cover of this report is a list of names of ORD people knowledgeable about specific topics. If you are interested in a particular topic or need any of the background information not contained in these brief summaries we urge you to contact us. Through such contacts you will get an even better picture of our programs and ORD may learn how research can be better used. In addition, we will learn of your concerns and be better able to assure that our research program responds to the major environmental concerns of our nation.

toxics

The effects of toxic substances are determined by ORD tests

The chemical industry is a constant contributor to contemporary American life. Synthetic fibers are now used extensively in the manufacture of clothing as well as for human body tissue replacement. Pesticides and fertilizers are important agricultural tools. Drugs save lives; plastics save money and weight. Millions of jobs are generated, billions of dollars exchanged.

However, the manufacture, use, and disposal of the everyday products that contain some of the more than two million recognized chemical compounds can present significant dangers, dangers that are often difficult to anticipate. Not until the release, for example, of tens of millions of pounds of polychlorinated biphenyls (PCBs) into the environment did scientists realize how toxic and persistent these compounds were. These PCBs, used in the manufacture of plastics, electrical transformers, and capacitors, have been found to collect in human tissue and even in the milk of nursing mothers. They have caused tumors, birth defects, and various liver anomalies in laboratory animals and are a suspected cause of some cancers. Although severely regulated since 1970, high levels of the chemical still exist in the Great Lakes and other major water bodies across the country.

Toxic Substances Control

In 1976, Congress enacted the Toxic Substances Control Act in recognition of the possible hazards posed by chemicals whose effects were yet unknown. The law charged EPA with the responsibility of anticipating potential chemical dangers, and authorized the agency to obtain available industry data on the production, use, and health effects of chemical substances and mixtures. Today, EPA reviews these data, evaluates chemicals for their carcinogenic, mutagenic, behavioral, and synergistic effects and determines whether they are free of unreasonable risk to health and environment.

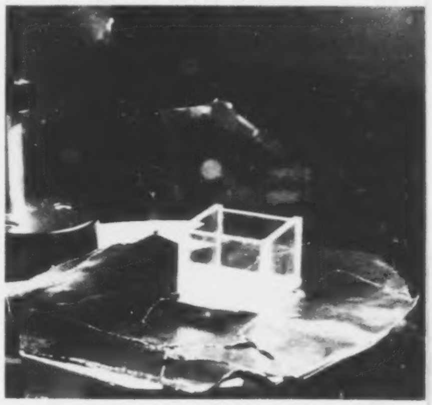
The size of the chemical industry, the number of compounds that exist, and their pervasiveness, all serve to make EPA's task particularly challenging. One basic approach being followed by ORD to meet this challenge is the development of an early warning system to anticipate potential environmental hazards. The system involves a series of rapid testing approaches to determine first, *what* chemicals are entering today's waterways, and second, what the effects of these new chemicals might be on tomorrow's environment.

Rapid Testing: The Survey Technique

A program to analyze thousands of industrial effluents or wastes for organic compounds thought to pose health hazards was begun in 1978. The analysis tool used in this program is a gas-chromatography-mass spectrometry system (see "Measuring the Minuscule").

This system, a single, comprehensive analytical procedure, is capable of identifying many organic substances in concentrations as low as 0.5 parts per billion. Once identified, the toxicity of a substance can then be determined using computerized access to an organic substance data base.

Test animals under video camera



Currently, ORD chemists are developing a protocol for the standardized analysis of 114 key industrial pollutants, a procedure complicated by the presence of dozens or hundreds of compounds in a typical wastewater sample. Information developed in these analyses and through additional surveys, along with health effects data already determined, will establish whether or not given chemical discharges should be limited or prohibited.

Actual Bugwatcher movement being observed on video screen

Rapid Testing: Bugwatcher

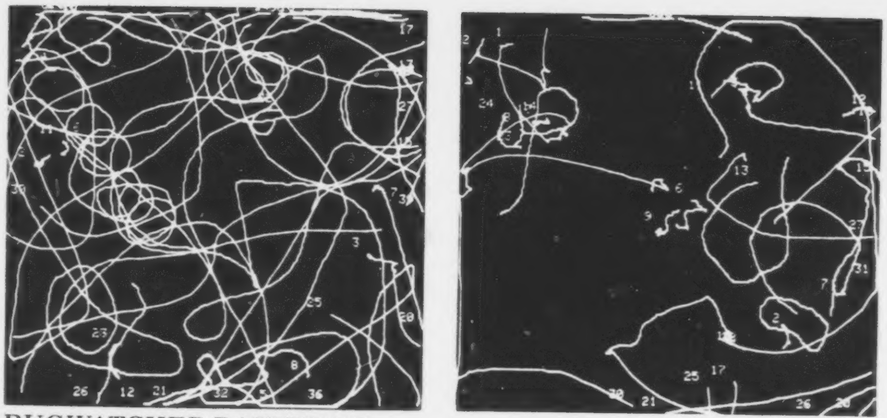
Changes in the behavioral characteristics of animals can be used as early indicators of physiological problems caused by toxics. Such behavioral changes may include shifts in an animal's response to light, the loss of the ability to sense the presence of food, and, in aquatic animals, a sharp increase in swimming speed which can lead to retarded growth.

In the past, short-term toxicity assays, taking as long as 96 hours to complete, have only provided researchers with the lethal levels of given test chemicals. Ecologically protective levels cannot, however, be determined from such assays since they are not capable of evaluating adverse nonlethal, but nonetheless harmful effects.

In the search for a better rapid assay method, Bugwatcher, a system capable of measuring the ability of small animals to respond physically to the presence of toxics, was developed in 1978. The Bugwatcher is actually a closed-circuit TV system that monitors and records a test animal's movement. The TV recordings are then analyzed by a minicomputer, which provides a numerical description of the rates and patterns of the movement.

In a typical experiment, the swimming behavior of 20 control and 20 toxicant-exposed animals is video-taped, then analyzed by computer. The computer draws the path traveled by each animal and calculates the various characteristics of their movement. The entire process takes only a few hours. With the statistical summaries derived from a series of such tests, it is possible to analyze a relatively large number of animals and their response to a toxic substance in a short period of time.

The system is now being evaluated to determine how broadly it can be applied to toxicity testing. From the results to date, the indication is that Bugwatcher is a powerful tool for the ecological assessment of chemicals, with significant potential for rapidly providing the information necessary for rule making, decision making, and the arbitration of disputes.


BUGWATCHER PATTERNS

Computer display of movement patterns

Rapid Testing: Evaluative Models

With the large number of new chemicals produced each year, EPA found it necessary to develop an economical, effective, and rapid means of forecasting the potential toxic effect in natural waterways as a result of their manufacture, use, and disposal. Field studies were considered to be too costly and too time-consuming, and, more important, such studies could provide information only after the fact. Consequently, research attention centered on developing laboratory techniques to forecast the length of time a given chemical remains toxic and where it collects in the aquatic system.

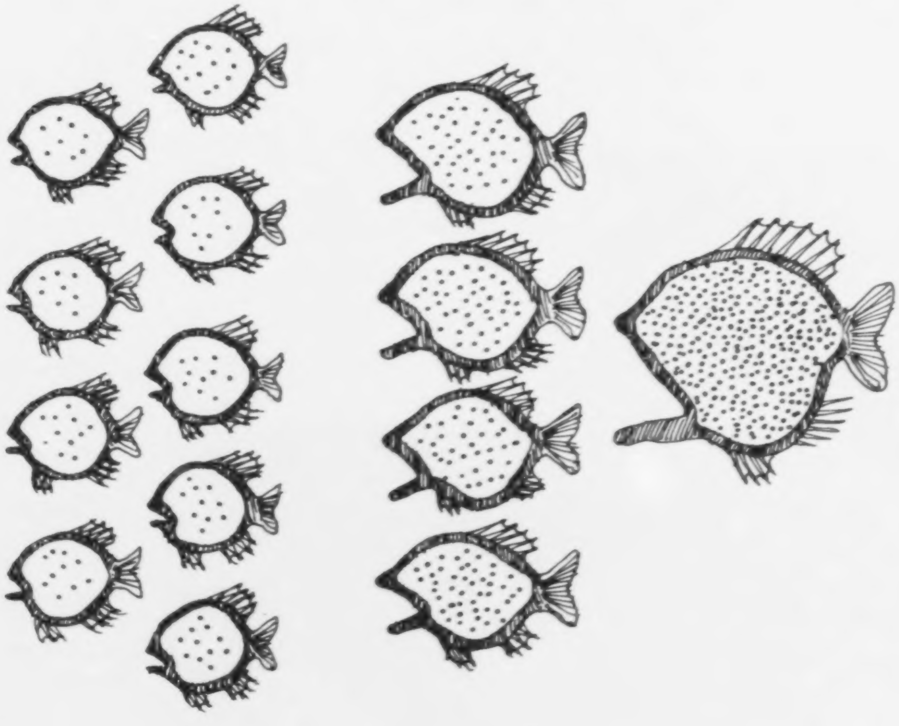
In 1978, ORD developed a computer model capable of delineating the environmental pathways followed by potentially harmful chemicals in freshwater systems such as ponds, lakes, and streams. Using this model, EPA researchers were able to evaluate the effects of nine chemicals that might be found in the effluents of fossil fuel production plants. Two pesticides were also modeled. One, Mirex, used to control fire ants in the Southeast, was banned because of its severe adverse environmental effects.

During the 1979 research year, the veracity of the results from these evaluative models will be tested using laboratory ecosystems and outdoor experimental facilities, and then such results will be further validated in field studies. If these evaluative models are proven to be sufficiently predictive, it is assumed that ultimately they will serve as effective rapid screening techniques. Such techniques will aid environmental decision makers in determining the need for the regulation of specific chemicals.

Rapid Testing: Bioaccumulation

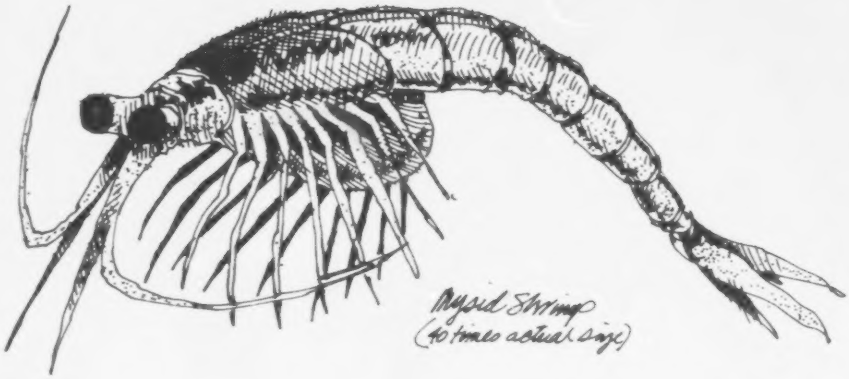
Bioaccumulation is the process by which certain plants and animals retain chemical pollutants in their cell tissues. Recently, the tissues of fish have been shown to concentrate low levels of dangerous chemicals such as DDT and PCBs, thereby posing a greater threat to those who eat the fish than to the fish themselves. In 1978, ORD studied the potential of certain substances to accumulate in fish. This research was devoted to determining the causes of chemical bioaccumulation and, further, to estimate bioaccumulation hazards before a chemical comes into widespread use.

It was found that bioaccumulation had directly to do with the amount of lipid, or fat, in fish tissues and the fat solubility of the chemical. Most fish contain significant amounts of lipid in their cell tissues. When a chemical only slightly soluble in water but highly soluble in lipids is introduced into a natural fish-populated waterway, the chemical tends to move from the water into soils and sediments and also into the lipids in the fish cells. It was also found that the chemical is distributed into fish tissues in proportion to the lipid content of the tissue. This fact led to a key result of the research: the amount of chemical found in fish is directly proportional to the amount of that chemical in the water. The ratio of the amount of chemical in the fish tissues to the amount of the chemical in the water is known as the bioconcentration factor.



BIOACCUMULATION

Further ORD research in 1978 was focused on developing a rapid and inexpensive method of measuring the bioconcentration factor of chemicals. This research showed that a bioconcentration factor can be accurately estimated from the fat solubility of a chemical. Experience has shown that fat solubility below a certain level means that a chemical will not bioaccumulate significantly. Consequently, new chemicals subjected to the quick test of solubility and found to fall below the critical level may not need to be tested. On the other hand, those chemicals above the level can be targeted for more extensive and expensive testing to see if indeed a hazard exists. Since approximately 70% of existing chemicals have fat solubilities that fall below the critical level, the cost and time of determining the bioaccumulate hazard have been substantially reduced by this ORD research.

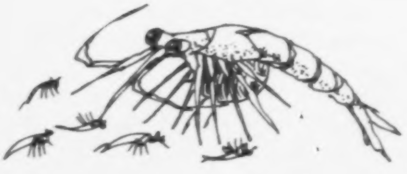
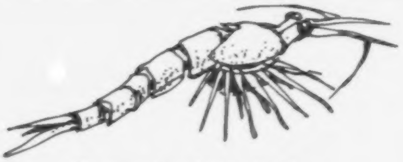

Mysid Shrimp
(40 times actual size)

Dimilin

In 1978, ORD performed a study on Dimilin, one of a new generation of insecticides designed to act in a specific toxic mode. In the case of Dimilin and the other "chitin inhibitors," death ensues through interfering with the formation of an insect's chitin, the hard outer-covering or exoskeleton.

Although much was known of Dimilin's effect on insect target species, little information existed on the insecticide's effect on nontarget species that might come in contact with Dimilin. EPA scientists wanted to find out, for example, the potential effect of Dimilin on marine and estuarine species that also formed chitinous exoskeletons.

Preliminary tests performed on a species of commercial shrimp showed they were susceptible to Dimilin. However, due to the high cost of laboratory monitoring during a shrimp's entire life-cycle (one year) and their general unavailability at proper stages of development, ORD chose a small mysid shrimp (14-16 day life-cycle) for an in-depth study of the effects of Dimilin on small marine crustaceans.

	CONTROL GROUP	NOMINAL TEST CONCENTRATIONS (ug/li)			
		.075	.25	.5	1.0
 juveniles per female	21.4	13.5	10.2	7.2	2.4
 % survival of adults	92.5	75.5	81.5	71.0	62.0

Toxic Effects of Dimilin

Test results from exposing mysid shrimp to Dimilin indicated the following:

- a toxic level of 2.0 parts of Dimilin per billion parts of water
- a lack of normal exoskeleton at the toxic level
- a diminished reproduction rate proportionate to increases in Dimilin concentration
- a reproduction rate correlating to the length of time of exposure
- younger shrimp were more susceptible to Dimilin than mature shrimp.

Dimilin was also found to affect successive generations of shrimp. If the shrimp matured in sublethal concentrations of the insecticide and produced another generation, this latter generation produced fewer juveniles, which died sooner than unexposed shrimp, a pattern observed even when this second generation was not exposed to Dimilin. It was assumed that this phenomenon could be attributed to the Dimilin being carried over in eggs. The third generation, however, was not found to be severely affected.

Implications

It is felt that if Dimilin in even sublethal levels were to be released in a marine environment that the crustacean assemblage may suffer severely. The disappearance or significant reduction of such small crustaceans could result in a diminished food source for both fish and the larger, commercially important crustaceans. Also, if these larger crustaceans—lobster, crabs, crawfish—were affected in a manner similar to their smaller mysid shrimp cousins, normal development and molting larval stages would certainly be altered, affecting subsequent availability, and possible suitability for human consumption.

Prediction of Dimilin Concentrations

As part of the evaluation of Dimilin in 1978, ORD used a prototype mathematical assessment model to estimate the potential impact on the estuarine environment resulting from Dimilin's application at recommended rates on upstream croplands. The study developed a mathematical representation of pesticide concentrations that might be expected if rain were to wash the compound into river tributaries that feed into nine river basins downstream from major U.S. cotton and soybean growing areas. An analysis of the pollution potential of the compound will aid decision makers in determining whether the use of Dimilin is a viable substitute for DDT.

Dimilin in the Future

In 1978, EPA granted a registration label for the use of Dimilin to control the gypsy moth, a pest destructive to hardwood forests on the eastern seaboard. Registration requests for other uses of Dimilin are pending. The decision for the extended use of Dimilin, proven extremely valuable in insect control, must be measured against the potential hazards it may pose. In 1979, EPA will continue to study the toxicity of Dimilin in nontarget species, its longevity in the environment, its ultimate fate, and the nature of chemical compounds formed by the decomposition of Dimilin.

The following ORD components contributed to the research described above:

- Office of Air, Land, & Water Use—Environmental Research Laboratory, Athens
- Office of Health & Ecological Effects—Environmental Research Laboratory—Gulf Breeze; Environmental Research Laboratory, Narragansett

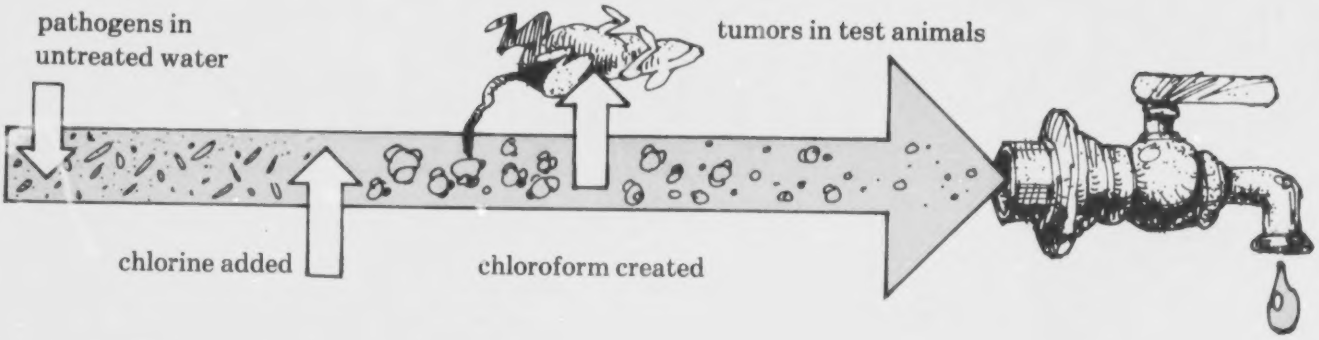
drinking water

The role of drinking water in cancer and heart disease is intensively studied by ORD

The fact that the quality of the water we drink may contribute to the incidence of the chronic diseases we suffer is yet to be firmly established. But several studies *have* shown that more than a casual relationship exists between the chemicals dissolved in our drinking water and mortality from heart disease and cancer, the two leading causes of death in the country today. EPA is investigating these relationships through its health effects laboratory in Cincinnati, Ohio.

Drinking Water and Cancer: Health Effects

In 1974, it was discovered that chlorine used to disinfect drinking water by killing pathogenic microorganisms also reacted with organic compounds in the water and produced chloroform. Chloroform was found by the National Cancer Institute's bioassay program to cause cancer in rats and mice. Epidemiological studies followed that compared chlorinated and unchlorinated water supplies, and although the results of the studies were mixed due to the number of confounding demographic and environmental variables, a definite correlation was indicated between increased rates of cancer mortality, (usually bladder cancer) and chlorination.



In 1975, EPA conducted the National Organics Reconnaissance Survey, the first comprehensive evaluation of the potential cancer hazard presented by drinking water. Under ORD auspices, data on the concentration of chloroform and other organic substances in drinking water samples was assembled and used in epidemiological studies which further supported the finding that increased concentration of these substances was related to cancer mortality rates.

Subsequent analyses of drinking water samples have turned up over 700 organic chemicals in the nation's drinking water supplies. While toxicological studies were conducted on a few of these individual substances, more effort was devoted to studying the cancer-causing potential of the complex organic mixtures as they occurred in the water samples. These organic concentrates were subjected to bioassay screening tests where they were shown to be mutagenic in bacterial tests as well as to produce transformations in mammalian culture cell lines. When these transformed cells were injected into mice, tumors were produced. The organic substances were, in other words, carcinogenic.

Based on these findings, EPA proposed regulations to control the concentration of chloroform and other organic chemical contaminants in drinking water.

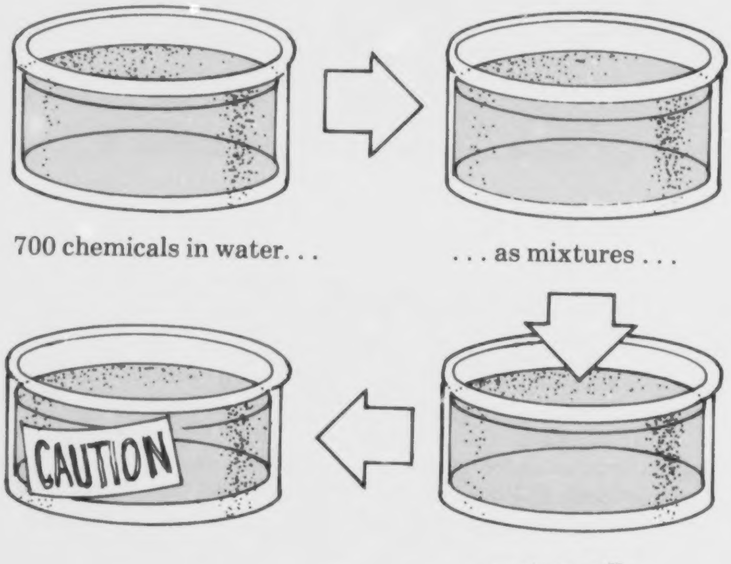
EPA in Water Treatment

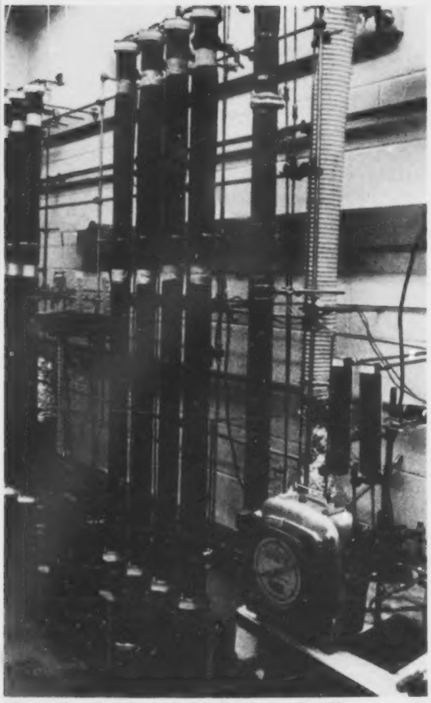
Within EPA, research is also being conducted to improve water treatment systems and to make them more economical. Methods of disinfecting water to make it safe to drink without producing chloroform have been developed through research done in the laboratory, in pilot plants, and at many water utilities. Numerous alternatives to chlorine are being studied, both for their effectiveness as disinfectants and for any inherent health hazards they may pose.

From this work, four general categories of organic treatment processes have evolved: precipitation, oxidation, aeration and adsorption. For the purposes of their treatment, organic contaminants were divided into five classes:

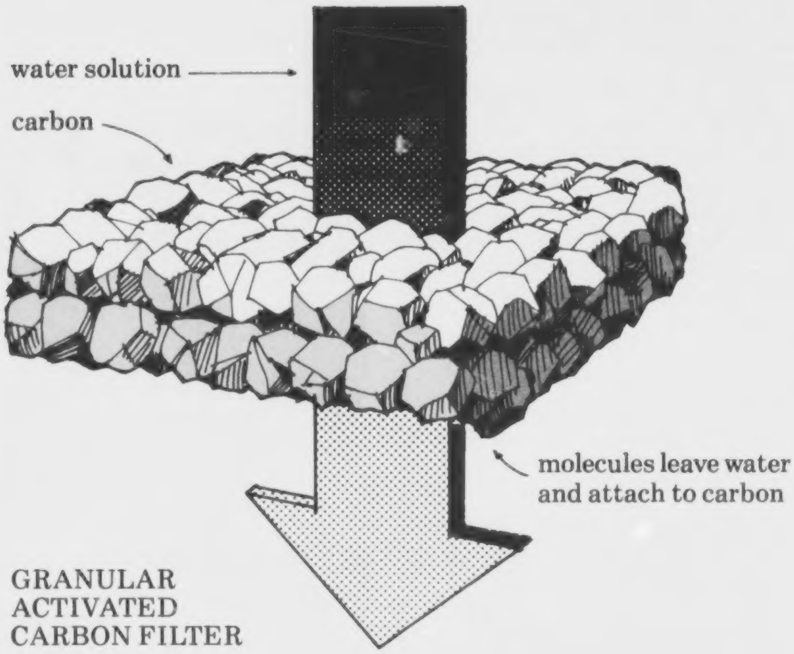
- Class I: organic compounds that cause foul taste and odor
- Class II: synthetic organic chemicals that are present in source wastes from upstream discharges or runoff
- Class III: organic compounds or "precursors" that react with disinfectants to produce "disinfection by-products"
- Class IV: organic chemicals that are disinfection by-products themselves
- Class V: naturally-occuring organic compounds, most of which are assumed to be relatively harmless.

Although all four treatment processes are effective in removing one class or another of organic contaminants to some degree, only one treatment, adsorption using granular activated carbon (GAC), has been demonstrated as an effective "broad spectrum" process for controlling organic contaminant concentrations.





Granular Activated Carbon test facility



water solution
carbon
molecules leave water and attach to carbon
GRANULAR ACTIVATED CARBON FILTER

Granular Activated Carbon

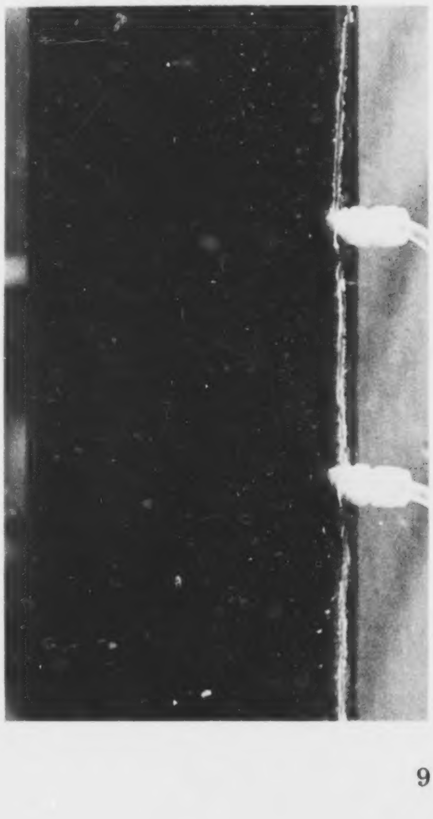
Adsorption GAC works as follows: Granular activated carbon acts essentially as an adhesive for the molecules of organic substances dissolved in water. As water is passed through a bed of GAC, organic molecules leave the water solution and attach themselves to the carbon by means of a physical bond, much like the glueing of one object to another. No chemical reacaction takes place. The molecules attached by this physical bonding are then easily removed or desorbed, by heating the GAC in a furnace which oxidizes the organic molecules causing them to leave the carbon. The GAC can then be reactivated for repeated reuse, an important factor in the economics of commercial GAC application.

GAC adsorption can effectively remove Class I compounds. Class II compounds, however, are variable in their adsorbability. Certain of these compounds such as pesticides or polychlorinated biphenyls (PCBs) are very strongly adsorbed, while other compounds such as carbon tetrachloride are less strongly adsorbed. But by frequent heating of the GAC to reactivate it, in the presence of these less adsorbable compounds, the process remains effective. However, economic and energy costs of this process are significant.

Because the problem of "precursors" and "disinfection-by-products" is relatively new and yet unexplored, little is known about the adsorbability of the organic compounds in Classes III and IV. In general, however, GAC is effective in the removal of most toxic organic compounds, and, if the carbon is kept "fresh," its effectiveness would be maintained.

Many Class V compounds are not readily adsorbed by GAC, but these compounds, in contrast to the others, are considered to be relatively harmless.

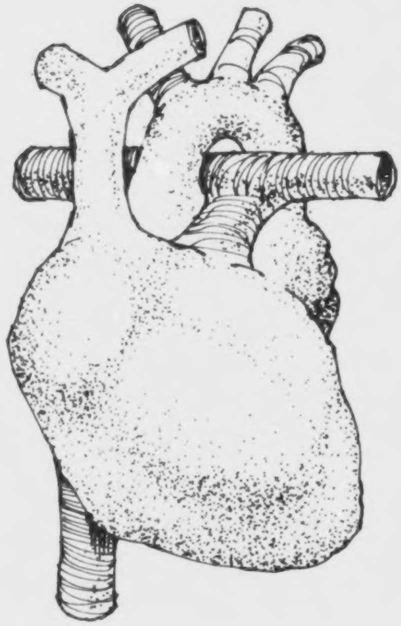
Close-up of carbon granules



Research Highlights

In 1978, additional research into the relationship between drinking water and cancer included:

- study of the use of asbestos cement pipe for a public water supply and the incidence of gastrointestinal cancer in Connecticut (Results showed no association between the two; fiber counts were low, however. In an epidemiological study in the San Francisco Bay Area where fiber counts were higher, higher cancer indicence rates were noted.)
- development and testing of a new, more sensitive analytical technique for monitoring polynuclear aromatic hydrocarbons in drinking water
- discovery that asbestos was found to increase the binding of benzo(a)pyrene to cellular DNA, indicating that asbestos may serve as a promotor of cancer
- obtaining and publishing data on the health effects of chlorine dioxide and its reaction products, chlorite and chlorate
- Testing the effectiveness and safety of six water treatment plants using GAC, no increase in endotoxin levels occurred after passage through the GAC filters.

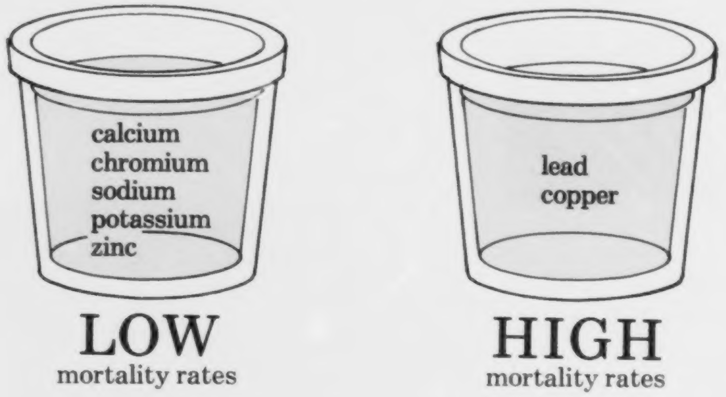


Drinking Water and Heart Disease

Studies performed in the 1960's to explore the relationship between drinking water and heart disease found a correlation between water hardness and the cardiovascular death rate in the United States. Follow-up studies demonstrated the same relationships for the metropolitan areas of the country. Death rates, in each instance, were lowest in areas that used hard water for drinking. But it was not determined whether there was something beneficial in the hard water, or if the soft water contained something detrimental. However, it was known that soft water was more corrosive and therefore more apt to pick up contaminants as it passed through distribution pipes and household plumbing.

Today, the most rigorous research on water hardness is taking place in Britain where cardiovascular death rates for white males are about 40% higher in extreme soft water areas compared with those in extreme hard water areas. In the United States, studies showed only a 15% difference. But these figures are based upon studies that compare an area's cardiovascular death rates with drinking water quality in the area. Such studies do not take into account all the disease risk factors that are necessary to provide solid clinical statistics, and for that reason there is currently not enough known by EPA about the relationship between drinking water and heart disease to consider regulation of the chemical content of water.

APPARENT PRELIMINARY FINDINGS CONCERNING WATER CONTENT AND CARDIOVASCULAR MORTALITY



Research Highlights

ORD is working to better define these relationships. A cooperative study by EPA, the National Heart, Lung, and Blood Institute and the National Center for Health Statistics on the cardiac implications of drinking water constituents is nearing completion. In this study, approximately 120 persons between the ages of 25-74 were randomly selected from each of 35 areas to provide a representative random sample of the U.S. population.

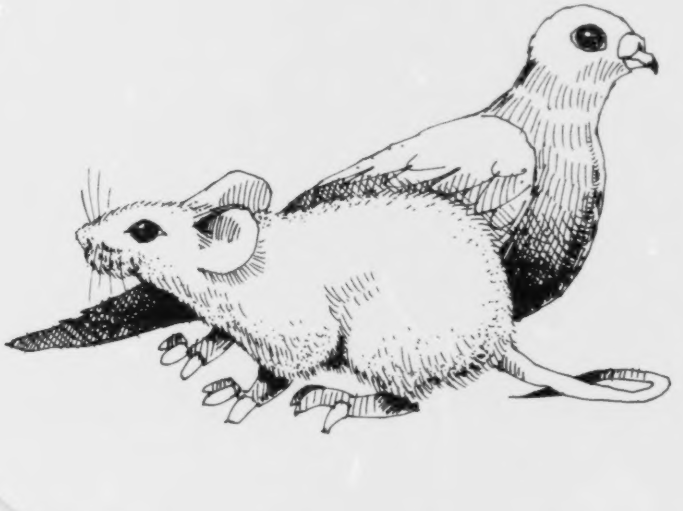
Each participant was first interviewed for (1) past medical history, residence history, socioeconomic status, smoking habits, etc., (2) water consumption, and (3) use of home softeners and conditioners. Participants then underwent a thorough physical examination.

Monthly tap water samples were collected over a period of a year, and materials used in the participants' home plumbing were cataloged. On the basis of the results of earlier studies, it was decided to characterize the quality of the samples for some 28 trace elements and other water-quality parameters that might be related to cardiovascular disease. To perform these extensive analyses, a single simultaneous multielemental technique called proton-induced x-ray emissions was used as well as more routine analytical procedures. Analysis of the data is in its final stages.

Before completion of this study, it was decided to determine whether the cardiovascular mortality rate for the regions in question was consistent with previous epidemiological studies. A preliminary analysis of the water quality data on 3834 tap water samples and the age-adjusted cardiovascular mortality data by sex for 1968-72 was completed. While conclusions cannot yet be drawn from the data, certain correlations and trends have been found. For example, it appears that regions with high pH, specific conductance and higher levels of hardness, calcium, chromium, sodium, potassium, and zinc in tap water have lower cardiovascular mortality, while higher cardiovascular mortality is found in regions with higher levels of lead and copper. These findings are in basic agreement with past epidemiological studies.

Two animal studies are also underway to supplement these findings. A contract has been awarded to the University of Mississippi Medical School to investigate the effects of calcium, magnesium, sodium, lead, and cadmium for hypertensive disease in rats. And an interagency agreement has been negotiated with the Oak Ridge National Laboratory to investigate the effects of calcium, magnesium, lead, cadmium and dietary fats in hardening the arteries of pigeons.

Technology research is also underway to determine the effects of corrosion on home and utility water pipes. If a relationship is demonstrated between some trace contaminant in corroding pipes and heart disease, such controls will be vital in the maintaining and safeguarding of the public health.



The following ORD components contributed to the research described above:

- Office of Health & Ecological Effects—Health Effects Research Laboratory, Cincinnati
- Office of Air, Land, & Water Use—Muncipal Environmental Research Laboratory, Cincinnati

groundwater

Methods to predict and detect groundwater contamination are developed by ORD

The 1974 passage of the Safe Drinking Water Act gave EPA the responsibility of protecting America's underground water supply. One of the country's most valuable natural resources, groundwater is available in greater quantity than surface water. Generally, it is also of better quality. Over half the population relies on underground supplies for drinking water. Groundwater supplies 20 large American cities and 96% of rural America's water needs. In addition, it provides drinking water for millions more in industrial plants, office buildings, restaurants, recreational areas, schools and other facilities that avail themselves of the resource.

In 1977, Americans tapped their underground reservoirs for a total of 70 million gallons daily, consumption that is increasing, by conservative estimates, at a rate of 25% per decade. The water exists to meet this demand. However, water resource planners are now realizing that while groundwater is in plentiful supply, it is also subject to contamination from a wide variety of sources. And once a given groundwater supply is contaminated, its quality cannot be restored naturally for decades or even centuries.

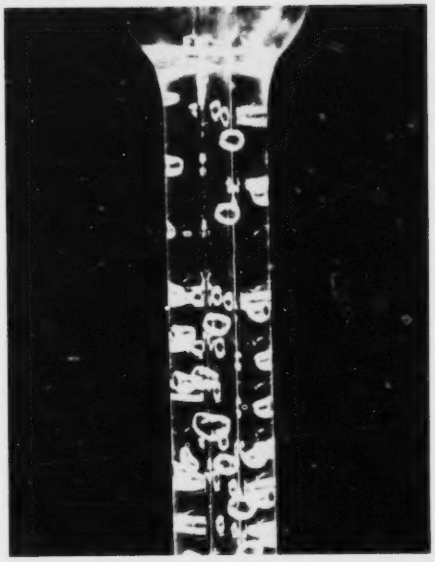
While man-made artificial methods of ground-water restoration are technically feasible, they are time-consuming and expensive. Rarely, in fact, can the cost of such restoration be justified by the resulting intrinsic value of the water. Consequently, ORD research goals are directed toward establishing the scientific basis for the development of sensible waste source control techniques to prevent contamination and protect the good water we still have.

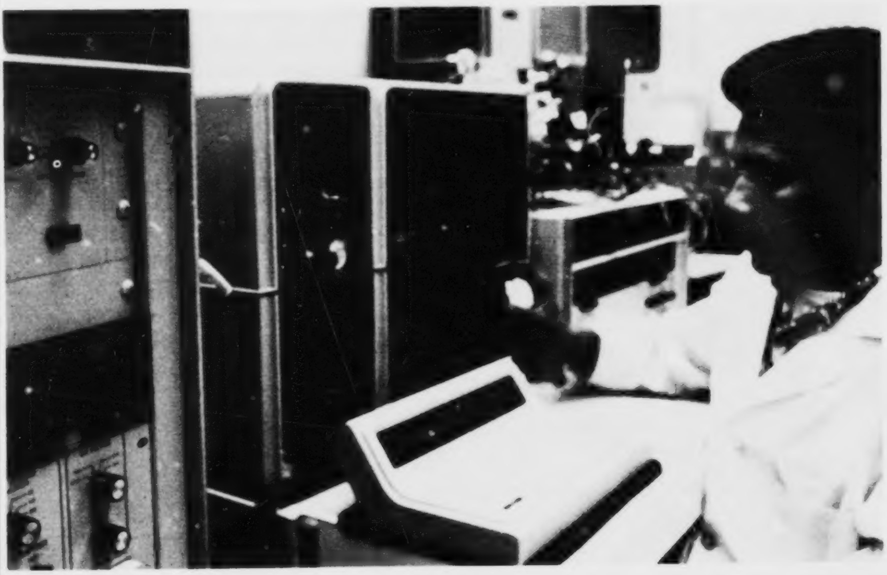
To this end, an ORD-sponsored groundwater information center was established to provide computer search services for specific topics of concern. In addition, the center acts as a clearinghouse for groundwater information gathered from around the world.

Following a survey and an evaluation of some 250 groundwater computer prediction models from fourteen countries, a centralized location for further model studies was established at Butler University in Indianapolis, Indiana. Here, water resource managers and others are provided assistance in selecting the proper models for their particular needs. Additionally, the Butler University center conducts workshops, bringing modelers and managers together to develop models that can be used more effectively and with greater efficiency.

In addition, to make as much current information available to as many interested parties as possible, the Fourth National Groundwater Quality Symposium was held in September 1978. A debate format was used to identify those issues that promised to be of paramount concern in the coming decade. Among the topics debated were groundwater quality standards, land applications of waste, federal and state protection and planning programs, and waterborne diseases.

Gas separation tube



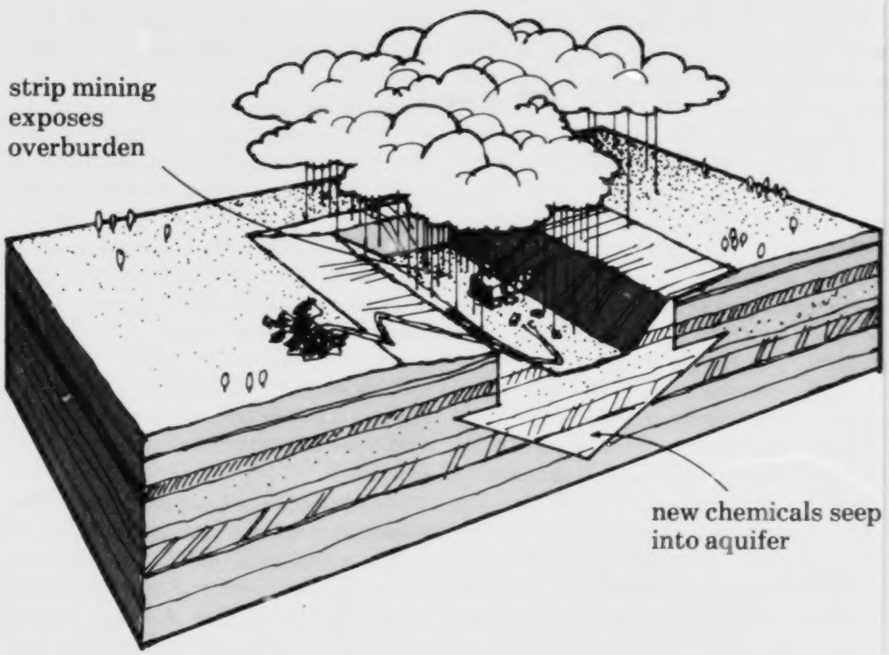


Research Highlights

A major focus of recent groundwater research has been on the development of methods to identify possible contaminants and to predict their tendency or ability to contaminate. It was found, for example, that the use of stable isotopes of nitrogen was effective in identifying certain sources of groundwater contamination. These isotopes were also helpful in differentiating between certain types of waste. Development of additional methods concentrated on ways to determine gross biological activity in the subsurface environment and to predict whether mixtures of organic solvents and water will migrate through clay to contaminate groundwater.

Another major area of research focused on how viruses and organic compounds were transformed and transported in the earth's subsurface. 1978 laboratory and field investigations provided much of the information necessary to characterize these phenomena. Specific studies involved tracing the movement of viruses from wastewater sprayed on land, through the soil column, and into the groundwater system. Attempts were made also to select accurate indicators of viral contamination.

ORD technical assistance was provided to a number of other EPA offices. These efforts ranged from the identification of trace organics in groundwater and the development of analytical methods for groundwater investigations to assistance in the planning and training required for a national study to evaluate the groundwater pollution potential of pits, ponds, and lagoons. Other technical assistance efforts were directed toward the development of information to support activities of the Safe Drinking Water Act.


strip mining exposes overburden
new chemicals seep into aquifer

Western Strip-Mining

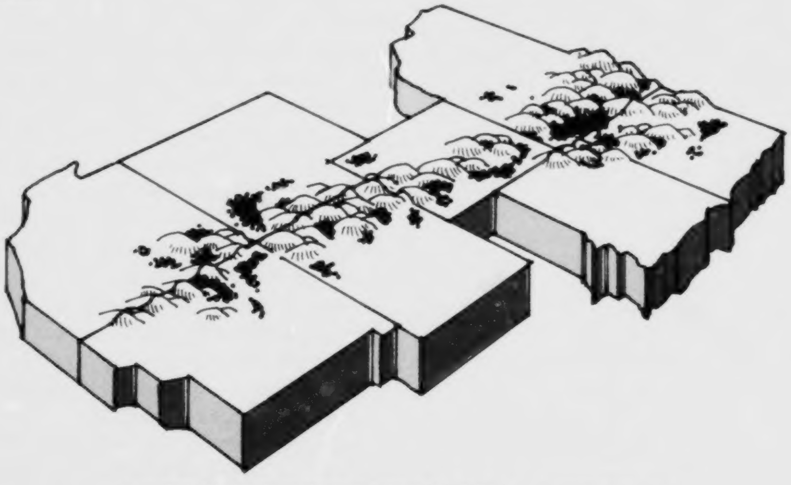
Strip-mining for coal is a process in extensive use in the West. Layers of earth are stripped away to provide access to coal as much as 150 feet below the surface, thus leaving tons of overburden exposed to the elements. When the inevitable chemical, physical, and biological erosion of the newly exposed surface materials in this overburden occurs, new chemicals are placed into solution, presenting a possible threat to groundwater systems. Such a threat can be averted if these chemicals can be attracted to other minerals in the overburden.

In 1978 ORD developed a technology that enables forecasting the potential effects of a strip-mining operation on groundwater quality, allowing for the identification of areas where such mining would not pose a threat to the groundwater system.

This procedure has been tested and demonstrated effective in numerous mines in New Mexico, Colorado and Wyoming, and will permit the accelerated extraction of coal from the vast western reserves.

Future Research

A substantial expansion of ORD efforts in groundwater quality protection is a key goal of 1979 research. A research plan has been developed based on suggestions from representatives of universities, consultants, state and other federal agencies, EPA regions and operating programs and other EPA research laboratories. Further support for this plan has also been gained from the EPA Science Advisory Board, the Drinking Water Advisory Council, and the Subcommittee on the Environment and Atmosphere of the House Committee on Science and Technology.



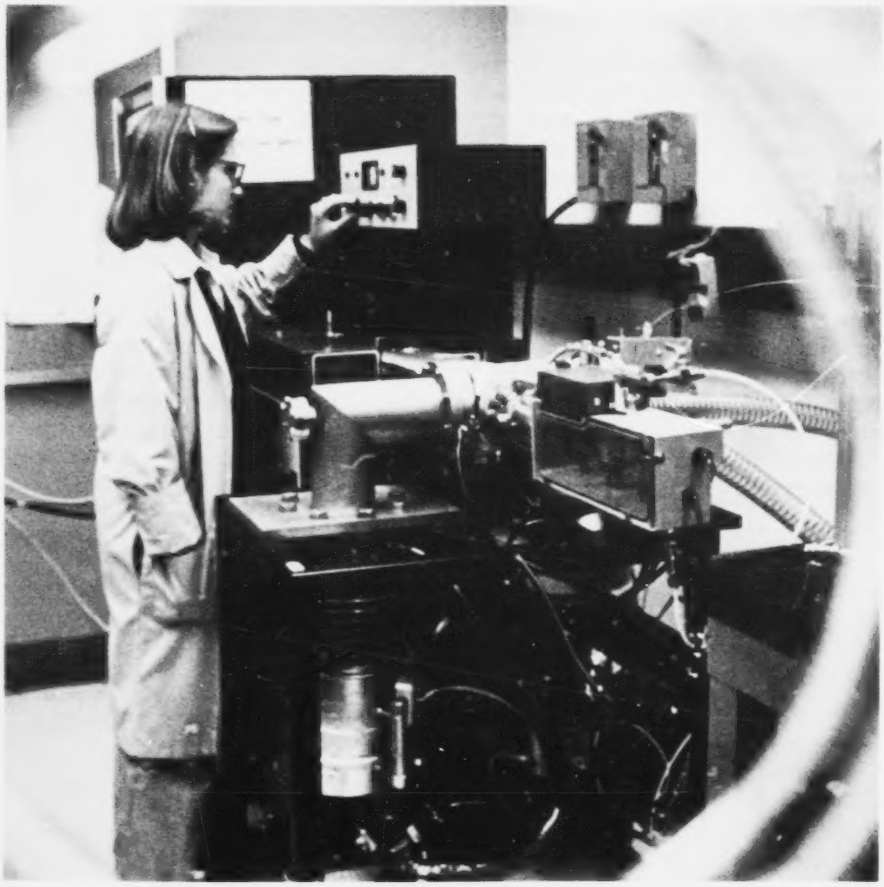
ACCESSIBLE WESTERN COAL DEPOSITS

The following ORD components contributed to the research described above:

- Office of Air, Land & Water Use—Robert S. Kerr Environmental Research Laboratory, Ada

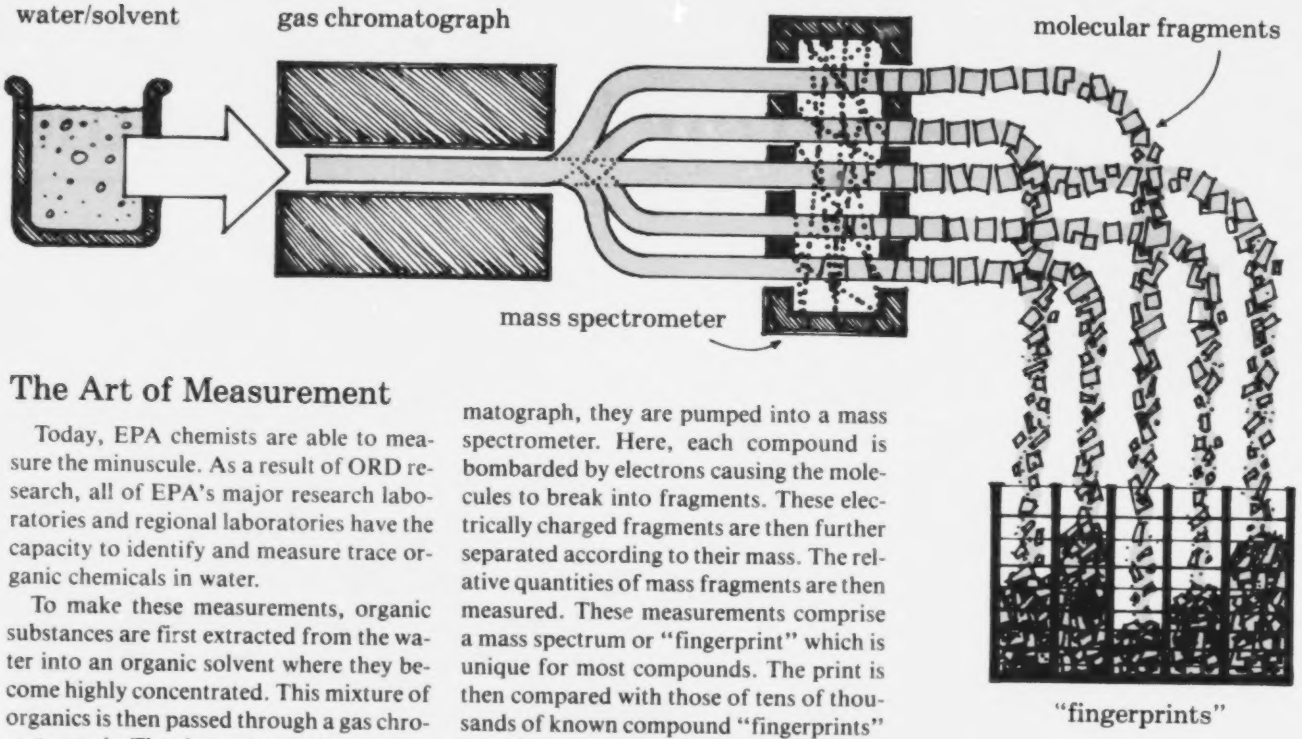
measuring the minuscule

Water contaminants are precisely measured by ORD techniques



No more than ten years ago water quality was determined by the chemical analyses of relatively few substances. High concentrations of magnesium carbonate and calcium carbonate, for example, meant that the water was "hard;" dissolved oxygen content was an indication of its ability to support fish life. As more and more new chemicals were introduced to waterways, however, EPA recognized the need for a more sophisticated approach to the determination of water quality. It had gotten to the point that it was clearly no longer a matter of answering the specific question "How much magnesium carbonate is there in this sample?" but far more inclusive ones such as, "*What* chemical compounds are present in this sample and in what quantity?"

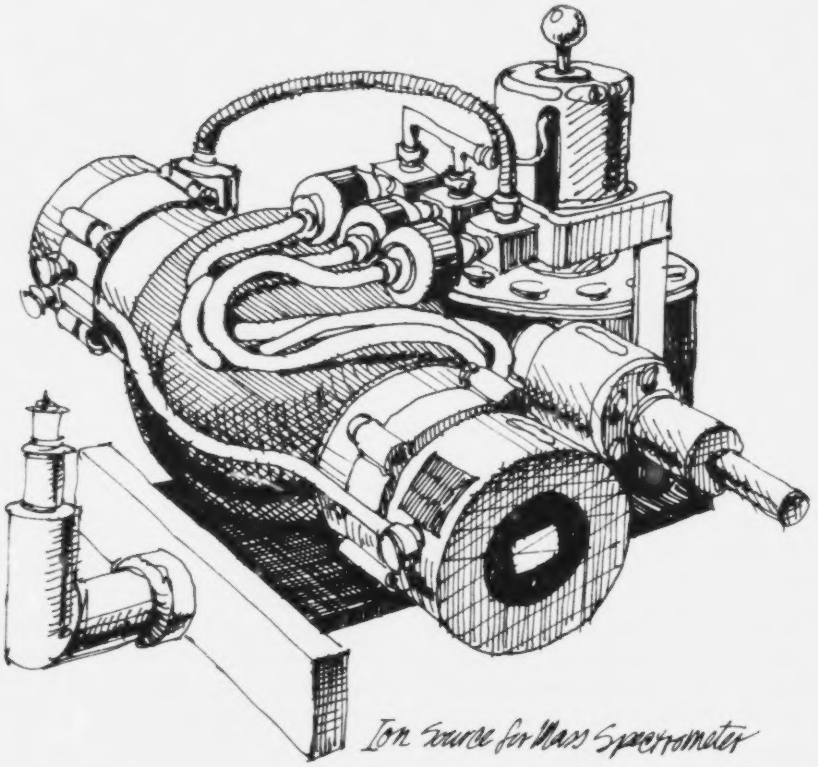
To provide the answers, it became necessary to be able to measure the minuscule. But how minuscule? A typical glass of water may contain more than a million different organic compounds, some of them potentially toxic in certain concentrations. At EPA, it is the chemist's job to identify and measure those that are present in concentrations above one part per billion. Although many of these compounds at such low concentrations are harmless, it is known that some toxic organic chemicals even at such low levels can kill fish or accumulate in the food chain in quantities sufficient to cause foods to fail Food and Drug Administration standards. Many of these compounds have also been shown to cause cancer in test animals when administered in larger doses than those to which humans are usually exposed.



The Art of Measurement

Today, EPA chemists are able to measure the minuscule. As a result of ORD research, all of EPA's major research laboratories and regional laboratories have the capacity to identify and measure trace organic chemicals in water.

To make these measurements, organic substances are first extracted from the water into an organic solvent where they become highly concentrated. This mixture of organics is then passed through a gas chromatograph. The chromatograph separates the individual compounds in the mixture based on the speed at which they pass through a long narrow column packed with a chemical "filter." From the chromatograph, they are pumped into a mass spectrometer. Here, each compound is bombarded by electrons causing the molecules to break into fragments. These electrically charged fragments are then further separated according to their mass. The relative quantities of mass fragments are then measured. These measurements comprise a mass spectrum or "fingerprint" which is unique for most compounds. The print is then compared with those of tens of thousands of known compound "fingerprints" stored in a computer library, and the substance is thus identified. The amount of a specific compound present in the sample is computed from the total mass of fragments associated with the compound.


Ion Source for Mass Spectrometer

Research Highlights

Recently, EPA chemists established a procedure using the gas chromatograph/mass spectrometer system to identify and estimate waterborne concentrations of 114 organic compounds designated as priority pollutants because of their potentially adverse health and ecological effects. Using this procedure, commercial laboratories have analyzed several thousand samples of industrial waste at an analysis cost per compound of approximately $7.00, or about the cost of a white cell count on human blood in a clinical laboratory. Analysis of a typical industrial waste sample costs approximately $300 due to the number of compounds to be measured.

In 1978, the EPA-developed gas chromatograph/mass spectrometer techniques were applied to the wastewaters of new types of energy-producing processes such as coal gasification, and to wastewaters from organic phosphorus pesticide manufacturing plants, as well as to municipal wastewaters. Hundreds of organic substances were identified and measured, many of which were not even suspected of being present. By applying such identification and measurement procedures to these wastewaters, it was possible to study those compounds that *actually existed,* rather than those that *might* have been present based on theoretical considerations.

Other 1978 research saw the development of an automatic sampler capable of extracting organic chemicals from water at the sampling site. The sampler can collect the toxic organic chemicals from hundreds of gallons of water onto a few grams of resin for transport back to the chemical laboratory.

Also developed during 1978 was a method of "cleaning" highly complex mixtures of organic compounds by passing them through a high-pressure liquid chromatograph before subjecting the sample to the gas chromatograph/mass spectrometer system. This cleaning process separates out two or three times more compounds in a given sample than without cleaning, thus allowing for the detection and recognition of difficult-to-identify compounds in the environment under requirements of the Toxic Substances Control Act.

600
500
400
300

Current research will extend EPA analysis capabilities to less volatile compounds that cannot be analyzed by the current system. Attention is also being given to reducing the cost of identifying very rare or new compounds whose "fingerprints" are not on computer file.

Additionally, research underway will develop and refine a Master Analytical Scheme, which will allow the analyst to look routinely for as many as 50,000 different compounds and simultaneously provide automatic quantification of any compound identified. To illustrate the value of such a system, had it been available for application to a few appropriately selected samples from the James River several years ago, the ensuing kepone problem might have been detected early and the resultant disaster averted. With continued research into the ability to measure the minuscule, EPA is looking to avoid the pitfalls of the past and to ensure water quality in the present and future.

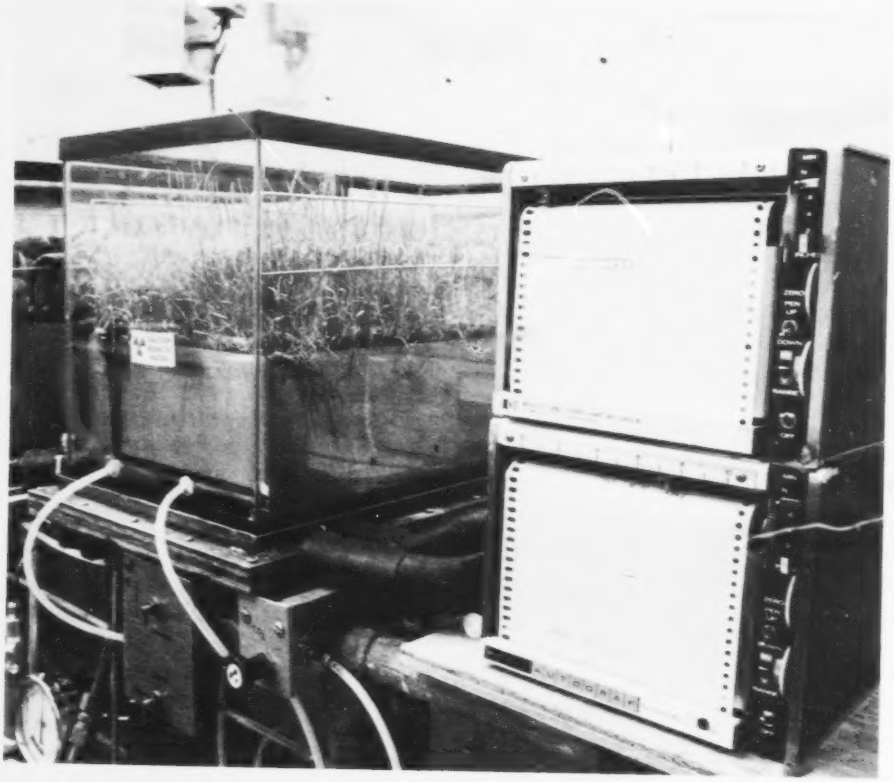
The following ORD components contributed to the research described above:

- Office of Air, Land & Water Use—Environmental Research Laboratory, Athens

simulating the environment

Enclosed ecosystems accurately represent pollution pathways

Isolated terrestrial ecosystems



The challenge of successfully simulating a natural marine ecosystem was undertaken by ORD in 1977 to assist EPA in the task of setting standards for the protection of our coastal zones. While a great deal was known about the toxicity of various pollutants and other stresses on individual organisms living in marine waters, far less was known about the effects on whole ecosystems. Particularly, little was understood about the pathways, fluxes, and transformations of natural chemicals and introduced pollutants through such systems. It was thus impossible to accurately predict the fate and impact of these substances on the ecosystem. Moreover, it was difficult to set optimal standards without a further look at the ecosystems. Because of the logistical complexities involved in studying a total natural system, it was decided to try to develop a small scale marine ecosystem model to mirror the natural system.

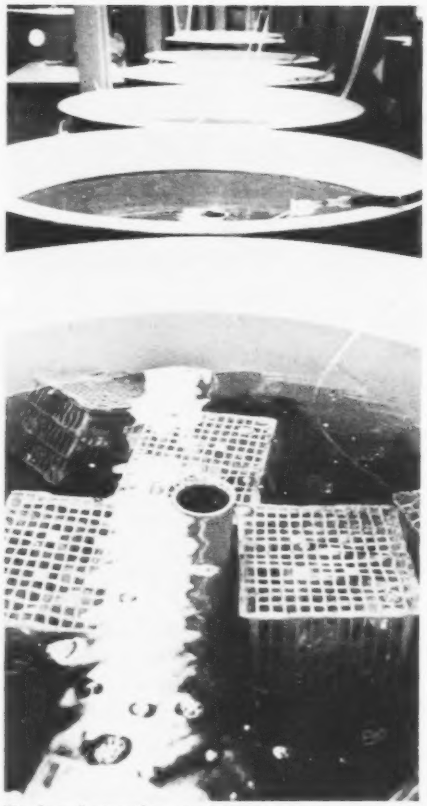
While it was difficult to know whether such a model actually would behave like its natural counterpart, every attempt was made in simulating the environment to duplicate the reference natural system. The same metabolic rate was maintained, and species diversity and composition were replicated so that major biological activities could be carried on in like ways. It was determined that if the statistical behavior of these species was similar to that of the natural system, then the model would be, in fact, a useful experimental tool, and perturbing effects and the rates and pathways by which various substances moved through the enclosed system might reasonably be extrapolated to the natural system.

A Major Initiative

In 1976 ORD initiated efforts to simulate such an environment. Specifically:

- to design, develop, and operate experimental marine ecosystems
- to investigate the behavior of these systems and the organisms that live in them
- to study various perturbing effects on individual species, species-species interaction, and on the properties of the whole system
- to investigate the geochemical and biochemical behavior of various elements and organic compounds in these complex enclosed ecosystems.

Outdoor environmental simulators



Enclosed aquatic ecosystems

Research Results

By 1978, these ORD research objectives were largely met, with some of the results considered a major breakthrough in research using simulated environments. Particularly gratifying was the fact that it was proven feasible to operate such enclosed ecosystems. The research showed that, in many aspects, the chemical and biological behavior of the microorganisms was surprisingly close to the reference regions in nearby Narragansett Bay on the Rhode Island coast. Where the systems diverged from those in the bay, operations were modified to overcome some anomalies. Where divergences persisted, a clear description of how the microcosms differed from the natural system was developed.

Today, difficult questions concerning the stability and resilience of coastal marine ecosystems are being viewed in a fresh light as a result of the work at Narragansett.

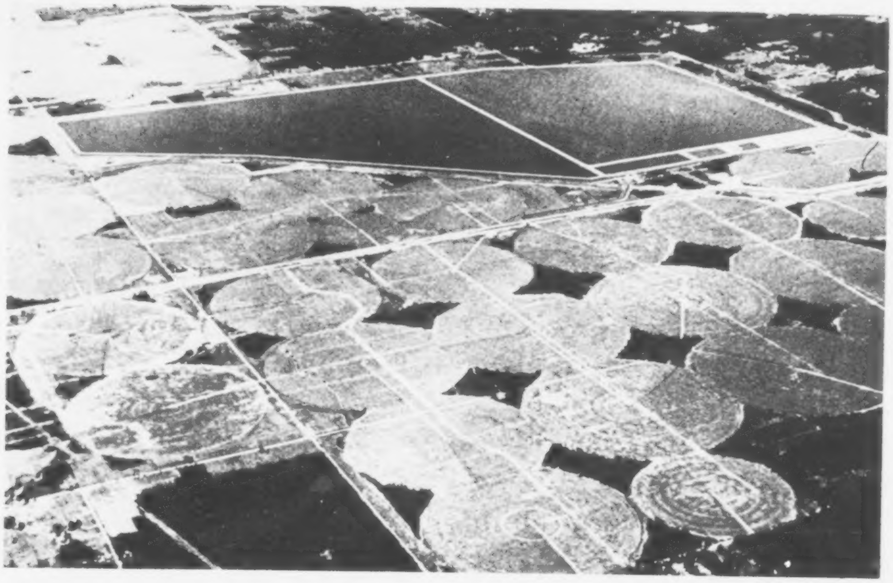
This successful simulation of a natural marine environment provides EPA with a dependable experimental tool with which to study the various effects of long-term, low-level exposures to the broadest variety of natural chemicals and human-made pollution.

The following ORD components contributed to the research described above:

- Office of Health & Ecological Effects—Environmental Research Laboratory, Narragansett

municipal wastewater

ORD evaluates effectiveness of alternative waste water treatment technologies



Wastewater is a problem that has plagued civilization for centuries. It produces a hazard to health and a blight on the environment, both aesthetic and ecological. In response to these concerns and the 1977 Clean Water Act Amendments, a broad range of wastewater treatment technology has been investigated by ORD. One technique, land treatment of municipal wastewater, shows the potential of being effective as a treatment process as well as allowing for the recycling and reclamation of valuable nutrients such as phosphorous, nitrogen and potassium.

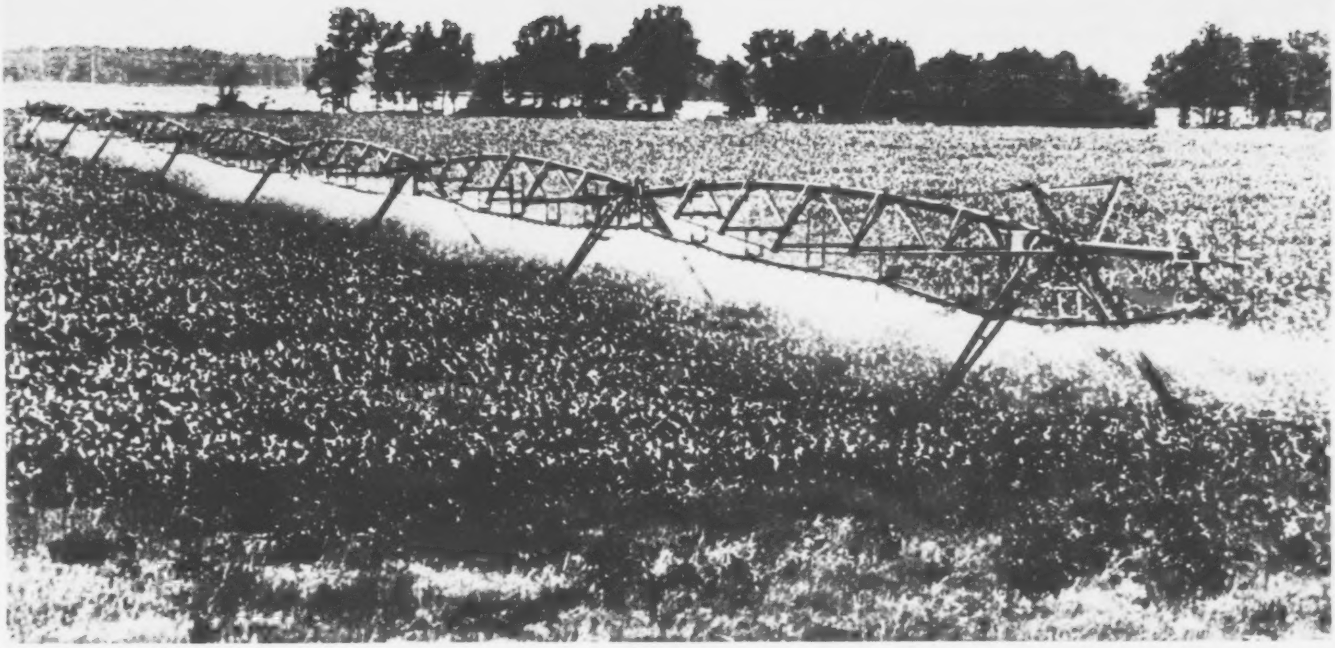
Health Effects of Land Treatment

Slow-rate land treatment involves the application of wastewater to the soil for the purposes of crop irrigation and fertilization, as well as for the removal of nutrients and other wastewater pollutants. By using wastewater to productively grow cash crops and, in turn, by using soil action and crop growth to partially purify the water, the land treatment process provides a potentially greater set of benefits than most other wastewater treatment techniques.

At the same time, this practice raises a number of health-related questions including:

- the fate and effect of waterborne pathogens such as bacteria, parasites, or viruses applied to the soil
- the risk to public health from these pathogens associated with spray application
- the fate and effect of hazardous organic materials and toxic substances applied to agricultural land
- the accumulation of heavy metals in foods grown on wastewater-irrigated land
- contamination of groundwater or surface water
- the spread of disease from carrier organisms living in the area.

Results of ORD research into these problems will assist EPA in developing criteria for land treatment systems.



Irrigation boom discharging municipal wastewater

Recent ORD Research

Aerosol sampling in one investigation revealed levels of microorganisms as far as 600 meters downwind of a wastewater spray application site. Observed microbial densities were twice as high at night than during the day and viruses were shown to be relatively hardy in the aerosol state. To estimate the microbial density at any downwind location from sprayed wastewater, a prediction model was then developed and calibrated.

A second study of aerosols generated by a wastewater treatment system included an epidemiological evaluation of persons living near the treatment plant as well as a study of the wastewater itself. While the wastewater in the plant contained microorganisms, they were not detected in a residential area 400 meters away. Further clinical examinations of nearby residents indicated no public health hazard.

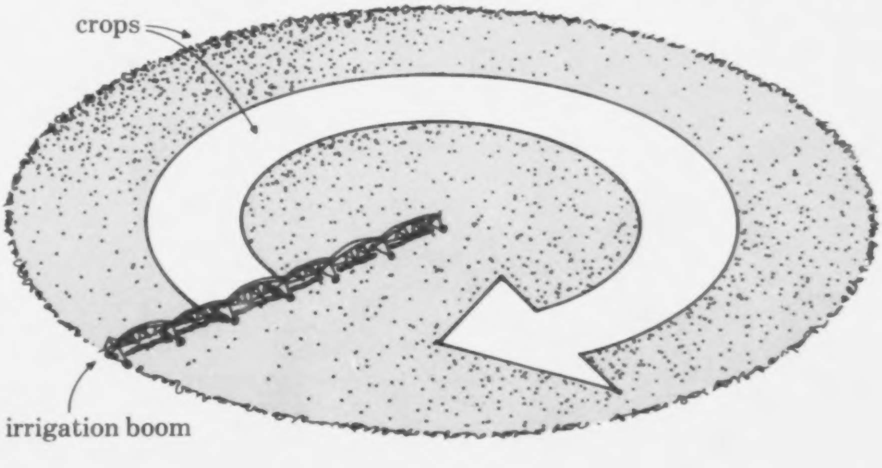
Soils

While most soils are generally effective in removing microorganisms from wastewater, 1978 research indicated that sandy soils are not, and are easily penetrated by viruses. These soils are especially vulnerable to penetration when they are stressed and saturated, and a heavy rainfall, it was found, may cause viruses previously adsorbed by clay and loam particles in the sandy soils to be released altogether, allowing them to sink deeper into the soils, thereby presenting a threat to groundwater aquifers.

Heavy Metals

ORD also conducted research into the uptake of heavy metals by various crops and the relative health hazards posed to persons consuming these crops. Since wastewater generally contains trace amounts of these heavy metals, care must be taken in using wastewater for irrigation. Certain crops such as leafy vegetables tend

LAND TREATMENT IRRIGATION



to accumulate metals in the edible portions of the plant. Most problems, however, can be minimized by not using wastewater to irrigate such accumulative crops on already acid soils.

Also, since heavy metals do not accumulate well in muscle tissue, an effective barrier in the food chain can be created by using the treated land to graze cattle.

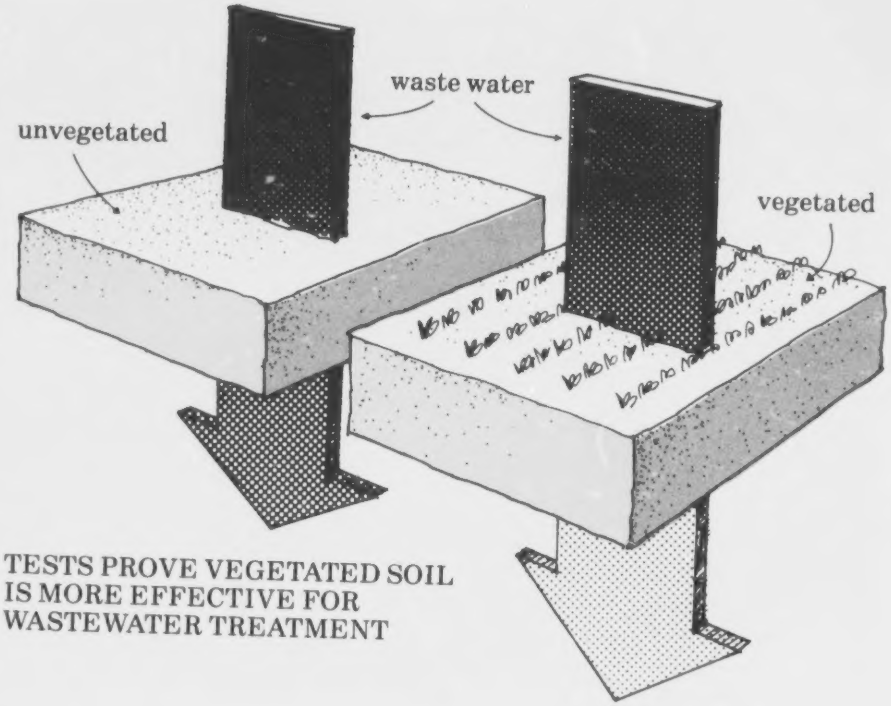
In general, it was concluded that the heavy metals in wastewater should not pose significant problems in the land treatment process.

Soil Treatment

In 1978, studies were conducted of ten existing land application systems treating municipal wastewater. Each system had been in operation for at least ten years. Four were rapid infiltration systems in which wastewater is applied on unvegetated coarse soil and contaminants removed as the water percolates through the soil. Six were irrigation systems that had a ground cover of crops. The study compared soil characteristics, vegetative response, and treatment effectiveness of the ten systems with controlled sites similar in operation and character. Detailed results of the study will be reported in 1979 but preliminary findings support the effectiveness of land treatment for municipal wastewater.

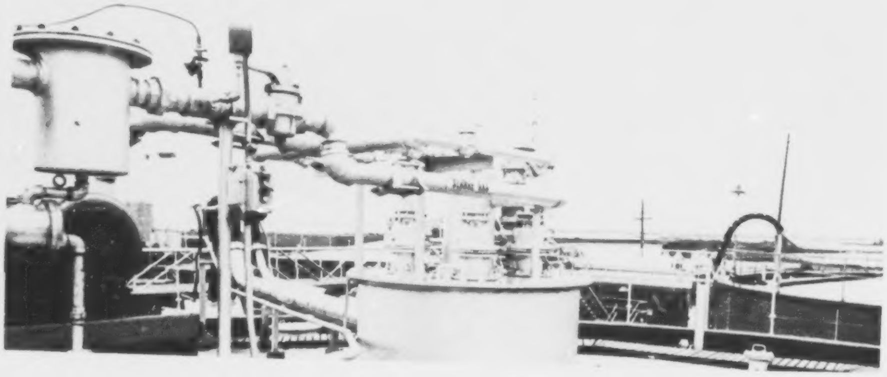
Small Flows

The small flows program provides EPA and other agencies with technological information about small community wastewater alternatives. Public interest in this program increased dramatically in 1978 as a result of the 1977 Clean Water Act Amendments. This year the ORD-sponsored program conducted 15 regional seminars on options available to individual communities. In addition, two one-week intensive training seminars attended by 100 state and EPA regional staff were held to review plans for small community wastewater system alternatives.



TESTS PROVE VEGETATED SOIL IS MORE EFFECTIVE FOR WASTEWATER TREATMENT

Wastewater treatment plant



Several analytical projects were completed and reported, including:

- septic tank pumping residuals treatment and disposal
- pressure and vacuum sewage costs and operational requirements
- systems for individual home wastewater disposal.

A comprehensive study on the technology of on-site wastewater treatment was also completed. It included research into wastewater characterization, alternative treatment systems, soil physics, soil clogging and unclogging, bacteriological and virological removal in unsaturated soils, and institutional alternatives for community-wide management of on-site systems. The study thus serves as a basic reference source for information about on-site systems.

Composting Sludge

The composting of municipal wastewater solids or sludge for land reclamation or agriculture is thought to be a desirable disposal alternative. Previous attempts at composting—a natural,biological decomposition process—were considered unsatisfactory because of problems created by compost pile odors.

In 1974 ORD initiated a research program in concert with the Agricultural Research Station in Beltsville, Maryland to look into composting alternatives for raw wastewater sludges. The process that was refined in 1978 utilizes wood chips in combination with the raw sludge to form the compost pile. Forced mechanical aeration allows some operator control of the process rate. The resulting compost is a dry, relatively easy-to-use organic soil conditioner that is essentially free of odors or pathogenic organisms.

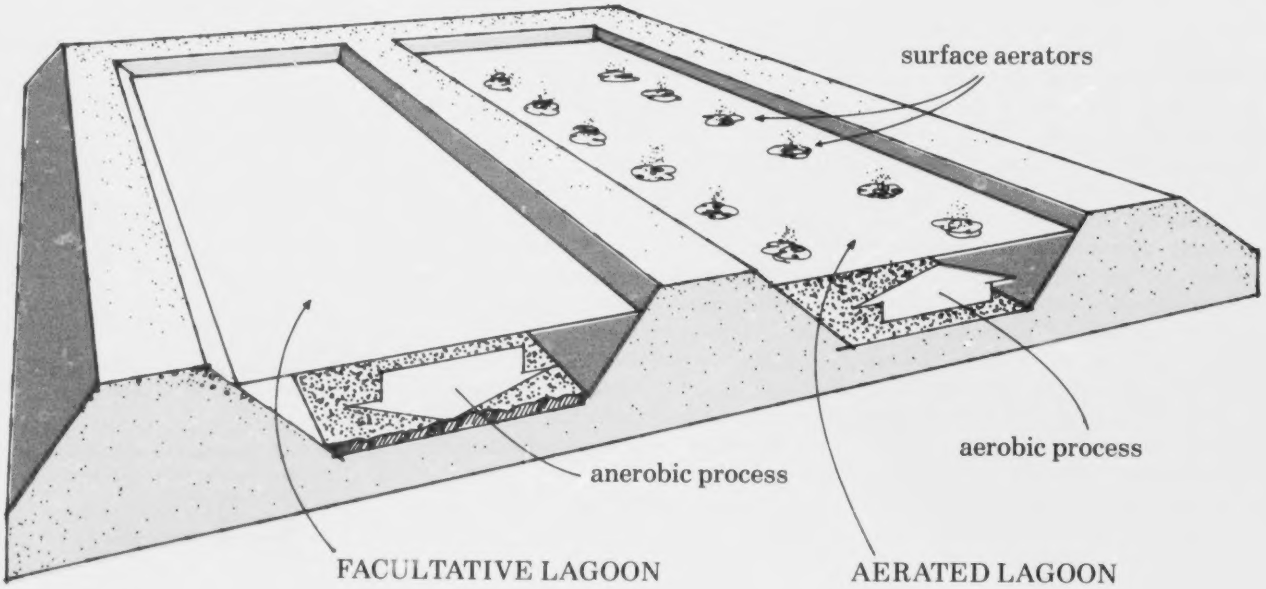
The Maryland Department of Health has approved the use of this Beltsville compost for turf farms, nurseries, golf courses, public works projects, reclamation projects, park lands and the establishment of new lawns. A number of other U.S. cities are also looking into the ORD wastewater sludge composting process.

Lagoon Performance

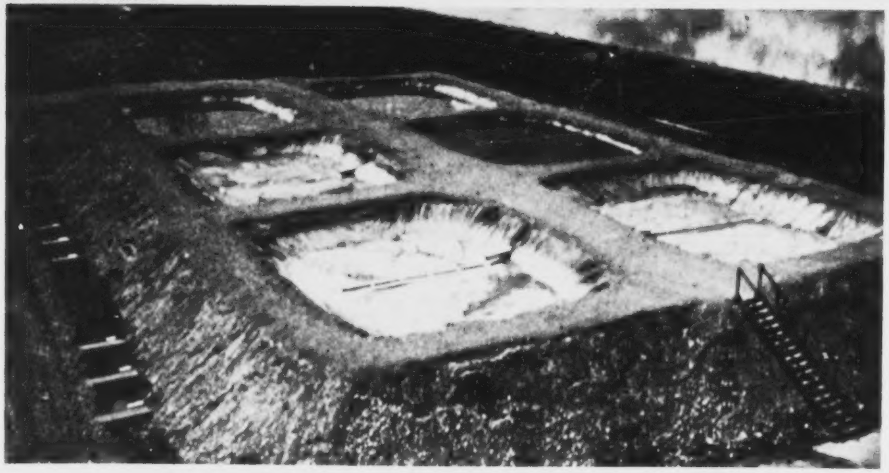
Oxidation ponds or lagoons where wastewater can be treated by natural biological processes have come into wider use over the last three decades. In 1945 there were 45 such impoundments in but a handful of states. Today there are over 4000 such lagoons in all 50 states. Ninety-three percent of these lagoons process less than one-half million gallons a day, indicating that their primary use is by small municipalities.

Lagoon systems are easy and inexpensive to design, construct, and maintain. This basic simplicity, however, often results in a lack of control over microbial and chemical reactions within these ponds. Until recently, in fact, little data even existed on the environmental effectiveness of these lagoons. For example, nothing was known that could be used to relate effluent characteristics to lagoon design or actual amounts the lagoon could effectively process, to variations in effluent load, or to climatic conditions.

A past report, however, based on the sketchy data available and a survey of state pollution control organizations, suggested that lagoon systems would not be able to consistently meet EPA suspended solids limits. Also, the report pointed to the obnoxious hydrogen sulfide odors, malodorous algae blooms, noxious vegetative growth, mosquito breeding and highly colored effluents emanating from the oxidation ponds. The report thus concluded that lagoons could probably no longer be used for wastewater treatment.



Slow sand filters



A design manual incorporating EPA studies and other work on lagoon design is in preparation to aid in the planning, construction, and operation of lagoon systems.

With proper design and operation, ORD research indicates that such wastewater treatment systems *can* be effective for treatment of municipal sewage. Their low initial cost of construction, ease of operation, reliability, and low energy requirement all serve to make lagoon systems sufficiently feasible and cost-effective for small communities.

EPA and Lagoon Systems

Over the past five years ORD has taken lagoon systems treatment under careful study. Factors affecting the treatment were examined, as well as the possibility of well-designed and well-managed lagoons being able to meet secondary effluent standards.

Four facultative and five aerated lagoon systems were intensively studied for a one-year performance evaluation. Aerated lagoons are basins with a constant flow-through of wastewater and a system of aerators to keep oxygen content high. The wastewater is treated by the action of aerobic processes. In a facultative lagoon, growth of algae near the surface provides oxygen allowing this upper layer to remain aerobic. Solid waste and some algae settle to the bottom. Treatment of the settled substance is by anaerobic processes.

The results of this research indicate that the lagoons could, in the main, meet EPA oxygen content standards required for secondary effluents. Only two of the nine lagoons tested failed to meet this standard; one, owing to excessive ice cover, the other with too few holding ponds or cells.

Suspended solids levels, however, consistently exceeded EPA effluent standards, especially in facultative systems. It was thought that this was primarily the result of algae growth, which is at its highest in the spring and summer months.

Fecal bacterial reductions, it was found, were a function of time spent by the effluent in the lagoons, and such compounds could be satisfactorily treated by chlorination.

Algae Removal

With algae growth primarily responsible for high levels of suspended solids in lag[illegible]ems, ORD initiated a program in 19[illegible]amine economical methods of algae removal. A pilot-scale slow rock filter in which effluents were pumped through a bed of rocks before discharge was studied at the University of Kansas.

A full-scale slow rock filter was built in Venata, Oregon, and evaluated at Oregon State University. Suspended solids were effectively removed by the system indicating successful algae treatment.

A pilot-scale intermittent slow-sand filter was also developed, and three full-scale intermittent slow-sand filters were built and studied. In these systems, a series of sand filters rather than a single rock filter acted as collectors in the removal of suspended solids. Design considerations included flow rate, hydraulic loading rate, filter area, filter number, and effective sand size. Besides removing most of the suspended solids from the effluent, the intermittent slow-sand filter allowed for the beneficial growth and activity of nitrifying bacteria, which served to make the treatment even more efficient.

Other work included further studies of lagoon effluent disinfection, nutrient removal from lagoon effluents, and phased isolation of lagoon effluents for removal of algae.

Algae bloom on wastewater

The following ORD components contributed to the research described above:

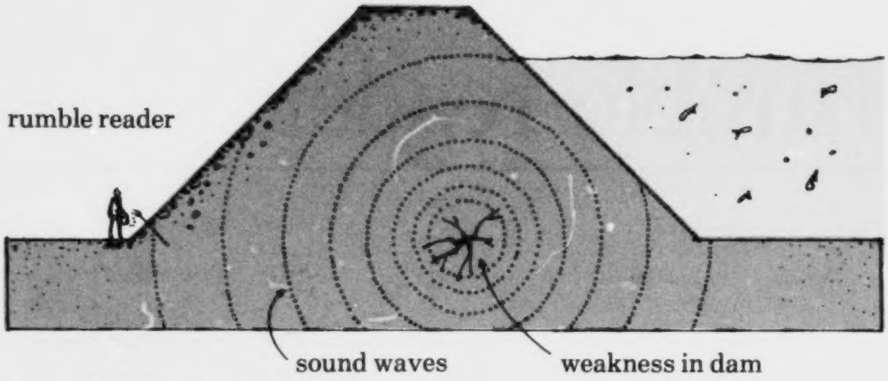
- Office of Air, Land & Water—Robert S. Kerr Environmental Research Laboratory, Ada; Muncipal Environmental Research Laboratory, Cincinnati
- Office of Health & Ecological Effects—Health Effects Research Laboratory, Cincinnati

rumble reader

ORD develops technology to warn of dam failures

A significant number of the hazardous materials impoundments in the United States are only marginally safe. Some, in fact, are ready to spill their contents into the nation's watercourses with as little provocation as a heavy rain, releasing contaminants that could pollute waterways, kill aquatic species, degrade drinking water, and despoil scenic areas. Even small spillages from these dikes can have potentially far-reaching environmental impacts.

With the existence of over 500,000 of these impoundments, ranging in type from small wasteponds to mile-square tailings lagoons, ORD is confronted with the problem of developing an assessment technology that can evaluate the stability of these storage areas on a regular and cost-effective basis. In response to this challenge, EPA fostered the development of the "rumble reader." This device, developed by Drexel University under a grant from ORD, uses acoustic emissions to sense the stability of impoundments.



CRITICAL MURMURS

Acoustic Emissions

When wood is overstressed it cracks. Tin "cries" when it is bent. Ice cracks. Snow crunches. In each instance, energy in the form of sound is emitted when stress is applied. In an earthen environment soil grains move against one another, clay strata slip and shear, particles shift as water seeps through porous earth. Here, too, noise is created, generally of low intensity, but varied in pitch.

Was it possible then to apply this same principle of acoustic emissions to the earthen dike walls that contained hazardous wastes? Did these walls, in other words, signal a weakening trend or a potential failure in the making? Exploratory research performed by ORD indicated that, indeed, they did. And that the sounds or "rumbles" in these dike walls could be read by instruments.

The principle of acoustic emissions is far from new. Early Westerners drove knives into the ground to pick up the sounds of herds of buffalo. Bandits put their ears to railroad tracks to gauge the approach of trains. In each instance, since the soil itself was a poor conductor of sound, they depended on a more effective "ear"—the knife or the railroad track.

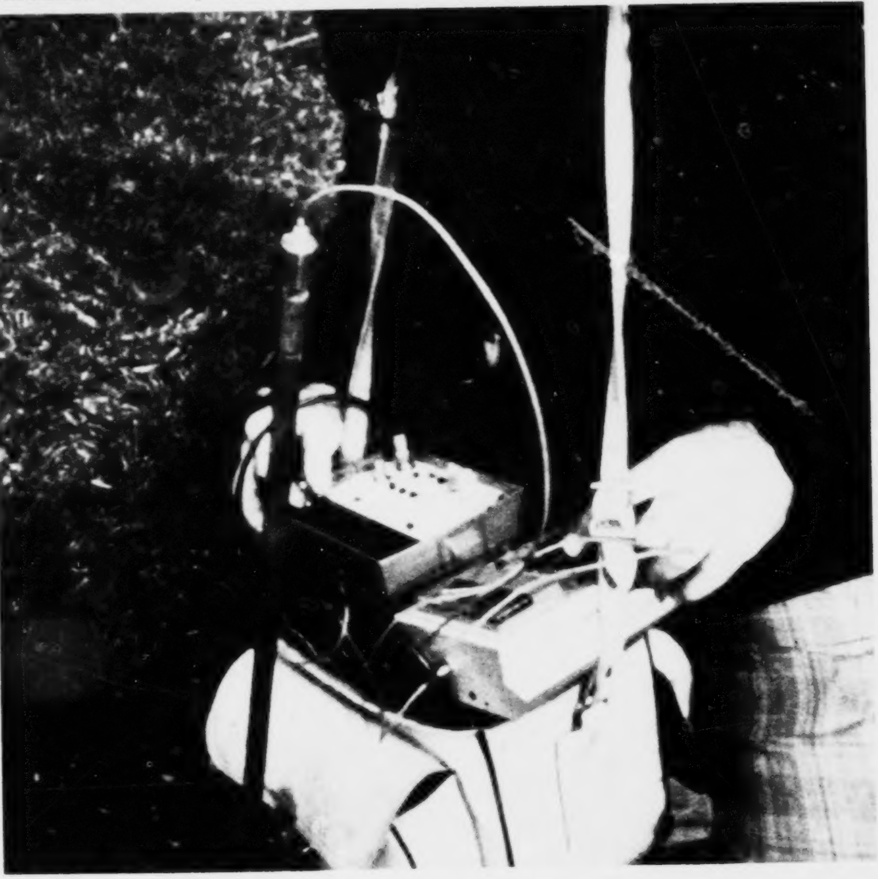
In measuring the rumbles emitted by earthen dikes, this same problem was encountered. Additionally, since early warning rumbles are feeble and occur deep within the soil mass, it was also necessary to develop a device capable of drawing these sounds to the surface where they could then be accurately measured.

The Technology

A quiet structure is safe and stable. A noisy one is in need of repair. Specifically:

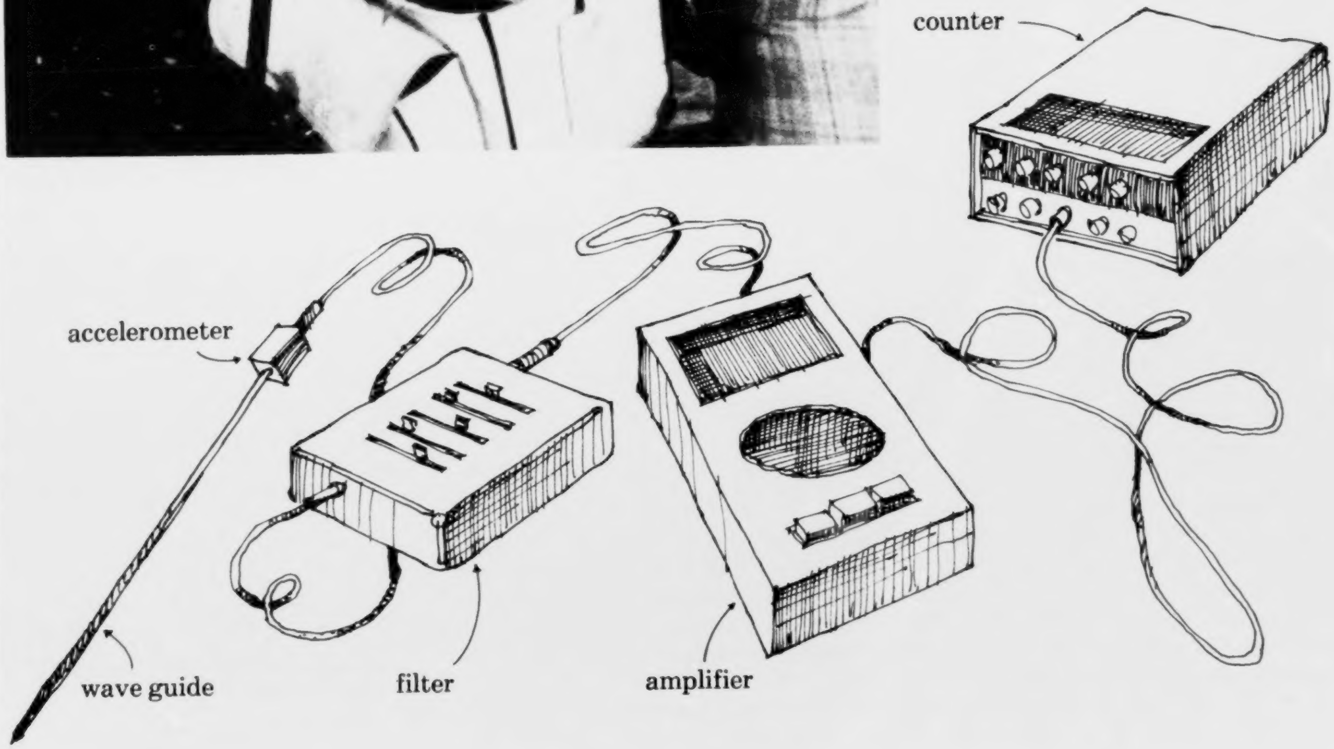
- Soil masses that do not generate acoustic emissions are not deforming and need not be inspected for a considerable time or until a new stress condition is encountered.
- Soil masses that generate moderate acoustic emissions are deforming slightly and must be monitored.
- Soil masses that generate significant acoustic emissions are deforming substantially and immediate remedial action is required—decreasing the stress on a dam or adding downstream berms, for example.
- Soil masses that generate high acoustic emissions are undergoing large deformations and are considered in a state of failure. Emergency precautions must be taken to assure the safety of downstream residents and property.

The Rumble Reader in portable form



The device that counts these emissions is basically a simple one. To sense the "rumbles," one-half inch diameter rods or "wave guides" of suitable lengths are placed in the dike being monitored for stability. A microphone-like device called an accelerometer is clamped to the end of the rod and connected to an electrical amplifier. The accelerometer converts the strength and pitch of the soil noise into electrical pulses which are amplified. These pulses are then processed by a portable counting and summing device to provide a "count-per-minute" readout.

The rumble reader system is portable and operates from self-contained lightweight batteries. At an equipment cost of $2000 to $5000, it is relatively economical, and data acquisition requires only 5 or 10 minutes per location and is easy to interpret. Furthermore, once a rod has been installed, the remaining equipment can be removed and reinstalled at will.



RUMBLE READER

Overview of sites being monitored using the acoustic emission method

Location	Purpose	Height (feet)	Length (feet)	Relative Embankment Design & Const.	Relative Foundation Stability
Pennsylvania	Flood Control	30	2600	Excellent	Excellent
Pennsylvania	Recreation	66	2500	Excellent	Excellent
Nebraska	Flood Control	67	900	Excellent	Compressible
Maryland	Ore Stockpile	40	300	Good	Very Poor
Pennsylvania	Surcharge Load	6	120	Good	Very Poor
Nebraska	Flood Control	68	600	Excellent	Compressible
Quebec	Tailings Dam	95	900	Good	Good
Delaware	Dredging Spoil	15-40	6 mi	Poor	Very Good
Pennsylvania	Water Supply	120	600	Excellent	Excellent
New Jersey	Chemical Wastes	8-20	4 mi	Poor	Very Poor
Virginia	Chemical Wastes	4-15	500	Poor	Unknown
New York	Petroleum Wastes	8-20	450	Poor	Unknown
Pennsylvania	Highway Fill	15	20	Poor	Good
Pennsylvania	Highway Fill	15	60	Poor	Good
Pennsylvania	Seepage Beneath Earth Dam	12	1200	Good	Poor
Kentucky	Water Supply	30	200	Marginal	Unknown
Texas	Chemical Wastes	100	3 mi	Good	Satisfactory

Research Highlights

Late in 1977, the rumble reader was a recipient of Industrial Research Magazine's IR100 award given to the 100 most significant new technical products of the year. By 1978 the rumble reader had been installed at 17 sites with locations as far west as Nebraska, north to upper Quebec Province, and south to Texas. The size of the embankments varies from heights of 6 feet to 120 feet and lengths from 20 feet to 6 miles.

Its effectiveness was shown in a number of instances. Failure of a suspected reservoir wall was easily predicted before collapse during drawdown of the impounded water. The sliding of an embankment was predicted hours before its actual collapse. A dangerously unstable industrial dike containing a sludge of dissolved toxic heavy metals was reinforced in time to prevent breaching. An abandoned lagoon at a chemical waste disposal facility was shown to be in danger of failure as it filled with water during a rainstorm; immediate action was taken and collapse was prevented.

Rumble Reading the Future

Several U.S. corporations have already installed the rumble reader at waste chemical lagoons, with hundreds of additional inquiries from private industry received by ORD. A large chemical manufacturer in England is in the process of procuring the rumble reader components, and at least two American companies are now supplying ready-to-use systems. Five U.S. Department of Agriculture dams have already been instrumented.

The ORD system need not, of course, be limited to measuring the stability of impoundments containing hazardous materials. All earthen dikes could be monitored, and tragedies such as those that occurred at Buffalo Creek, West Virginia (2/26/72), Grand Teton, Idaho (6/5/76), Laurel Run at Johnstown, Pennsylvania (7/20/77), and Taccoa, Georgia (11/4/77) could be averted.

The following ORD components contributed to the research described above:

- Office of Energy, Minerals, and Industry—Industrial Environmental Research Laboratory, Cincinnati (Edison, New Jersey)

assistance/emergencies

ORD can provide rapid and intensive technical assistance

Oil slick at EPA test facility

ORD constitutes a reservoir of talent in scientific and technical fields that serves EPA as an immediate response force for special action and emergency situations. These special responses are in addition to more conventional activities carried out by ORD, yet the aid provided in these instances can lead to future, longer-term research projects. During 1978, some of the assistance/emergency work undertaken by ORD included technical support for a consent decree concerning water regulations, special studies for air emissions from coke ovens and steel plants, reactions to natural disasters such as floods, and clean-up of hazardous and toxic chemical spills.

Consent Decree—Water Quality

A major ORD function is to assist other EPA branches and offices in fulfilling their various regulatory responsibilities. One such responsibility is the establishment of viable and enforceable effluent guidelines necessary to control point sources of water pollution.

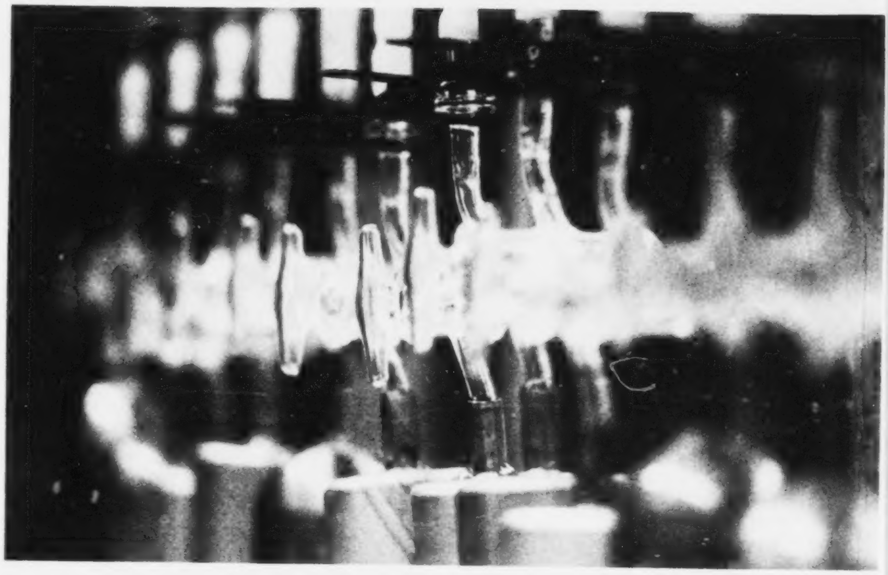
To provide the regulatory support required by various EPA branches in the fulfillment of these responsibilities, ORD conducts programs in the following areas:

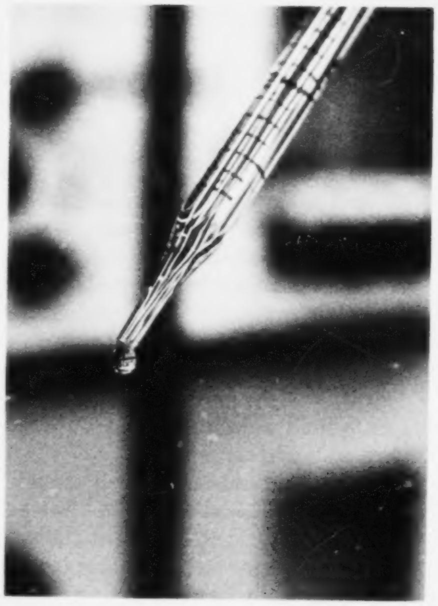
- determination of the physical, chemical and biological characteristics of industrial discharges
- technical and economic assessment of existing and emerging control alternatives
- development of human health and environment assessments to estimate the threat presented from exposure to ambient water pollutants
- determination of the "treatability" of specific pollutants or pollutant classes
- exploration, evaluation, development, and demonstration of new or improved treatment and control methods and concepts
- development and validation of analytical methods and monitoring systems for physical and chemical pollutants
- quality assurance services related to all programs as well as to the sampling and analysis activities of the Effluent Guidelines Division (EGD)
- determination of best management practices which may be applied to nonprocess operations of a point source—e.g., spills, runoffs, etc.

In June 1976, EPA signed a consent decree to review existing effluent guideline regulations for controlling 65 pollutants in wastewater effluents from 21 major industrial categories. The technology based effluent guideline regulations include:

- the best available technology economically achievable for *existing* sources (BATEA)
- the best demonstrated technology available for *new* source performance standards (NSPS)
- pretreatment requirements prior to discharge to publically-owned treatment systems for both existing sources and new sources.

One of the most significant consent decree support activities provided by ORD in 1978 was performed by ORD's four ecology laboratories. Here, guidelines for the development of water quality criteria necessary to protect aquatic life were developed, as a basis for the preparation of criteria for each of the 65 consent decree chemicals from the existing toxicology data base. These guidelines were published in the *Federal Register* for public comment, and it is anticipated that they will become EPA policy.





During the third and fourth quarters of 1978, using the guidelines, the ecology laboratories went on to develop the actual aquatic criteria documents. In companion fashion, the ORD health effects laboratory in Cincinnati initiated a crash program to develop health assessments for 20 of the 65 consent decree chemicals. This initial phase was completed in 1978 with continuing work on the initial 20 and the remaining 45 chemicals undertaken by a new environmental criteria and assessment office in Cincinnati.

Beginning in March 1979, both the aquatic and health based criteria will appear in the *Federal Register* for public review.

With the preparation of the guidelines and criteria documents, numerous information gaps and data deficiencies for the consent decree chemicals were identified. It was thus possible to establish priorities for further research.

In support of consent decree effluent guideline requirements, ORD is active in a number of specific research areas. In the pesticide and textile industry, a large number of plant sites were sampled in 1978 to measure the effectiveness of advanced technologies (such as carbon adsorption) in their control of the priority toxic pollutants.

ORD, at the request of EGD, also performed a study of 11 industrial treatment systems to determine the fate of a number of the priority pollutants in water and the air and to determine in what form the pollutants would tend to concentrate (e.g., oily sludge). The industries included: wood-preserving, chemicals, pesticides, pharmaceuticals, rubber, and plastics. Results of this study will be available early in 1979.

Twelve refineries were sampled for EGD in 1978 to characterize and to some extent measure the priority pollutants entering and leaving treatment systems. Refineries were also studied to determine *how* activated sludge systems worked to remove hydrocarbon pollutants.

An additional project carried out for EGD involved pollution evaluation of the petrochemicals/organic chemicals industry. Here, wastewater treatment facilities were sampled to indicate the fate of priority pollutants entering the system. Additional evaluations were made to determine whether less costly effluent treatment procedures might be applied with positive effects. (See "Measuring the Minuscule" section)

Coke Emissions and Air Quality

At the request of the EPA Office of Air Quality, Planning and Standards (OAQPS), ORD undertook three projects in 1978 in support of the development of a national emissions standard for coke plants. The first project involved the measurement and analysis of emissions from coal preheaters, devices that dry coal and raise its temperature to approximately 550°F before its introduction into a coke oven. The study is not yet complete, but preliminary results indicate that these emissions contain some benzene-soluble organic compounds, many of which are known to be carcinogenic.

A second project assessed coke quenching operations. Here, coke is cooled by the application of water after it exits the coke oven. The study was designed to determine whether or not hazardous air pollutants, principally carcinogenic organics, were released when the water came in contact with the hot coke. Since the coke is quenched with clean water in some plants and with contaminated process water in others, tests were made under both conditions. Preliminary results indicate the presence of polynuclear hydrocarbons, an organic class of compounds which includes many carcinogens. The amount of these materials is increased tenfold when contaminated quench water is used.

The third ORD coke emissions project evaluated seven separate sources of air emissions in coke by-product plants. Benzene, a known carcinogen, and small amounts of an organic substance containing carcinogenic compounds were identified from a number of these sources.

The results of these three projects provide OAQPS with the only data available on hazardous emissions from these particular coke plant sources. In addition to becoming part of the extensive fund of data on which to base the eventual setting of specific standards for the cokemaking industry, ORD test data will assist OAQPS in making the effective long-range planning decisions for future research to support final regulation.

Quality Assurance

Measurements of environmental samples are made daily by federal, state, local and private agencies. These data are then used in the assessment of health effects, the establishment of environmental standards and guidelines, and the enforcement of environmental regulations. To help assure that such measurements are precise and reliable, EPA established a quality assurance program to aid in the development and implementation of widescale quality control procedures. ORD's environmental monitoring laboratories in Cincinnati, Las Vegas, and at Research Triangle Park, North Carolina, bear the responsibility for the successful development of this program. 1978 research highlights include:

- initiating a program to check laboratory performance in those agencies charged with measuring air pollution, to include a set of minimum quality assurance standards to be observed
- providing a wide range of reference water samples for use in maintaining day-to-day laboratory accuracy
- providing audit water samples to evaluate laboratory data qualilty and analysis capabilities
- providing radioactive environmental samples to laboratories to evaluate their data analysis capabilities
- assisting laboratories by providing accurately calibrated radioactive samples for use in new instrument calibration and other analytical procedures.

Thunder Bay
Duluth
Toronto
Buffalo
Detroit
Milwaukee
Chicago

GREAT LAKES REGION

Pesticides Plant Explosion

A rapid, considered response to environmental emergencies is one hallmark of ORD's overall responsibility. When a pesticide plant in Vicksburg, Mississippi, exploded in March 1978, releasing a pesticide cloud, ORD took quick action. There was the clear possibililty of danger to the exposed population from either inhalation or other longer-term contact with the pesticide. ORD needed to locate concentrations of deposits from the cloud, measure the content of those concentrations to determine the health risk, and determine appropriate action to protect the Vicksburg populace. Analytical samples taken of the immediate environment fortunately revealed no substantial contamination of air, water, or soil. Continued ORD monitoring for environmental dangers determined that the pesticides released during the accident did not contribute to the existing burden of chemicals in the area and that exposures from the explosion were transient.

International Support/Cooperation

The Great Lakes comprise 95% of America's surface waters, and their welfare is a major EPA concern. The fact that they are part of our northern boundary and are of international importance compounds the complexity of efficient pollution control in this region. In 1978, a U.S./Canadian Water Quality Agreement was signed. This revision of a previous five-year document gives new emphasis to control of chemicals in the Great Lakes and continued emphasis to nutrient control and nondegradation. Additionally, emphasis is given to an ecosystem approach for the exploration and solution to water quality problems.

Two problems are currently of paramount concern:

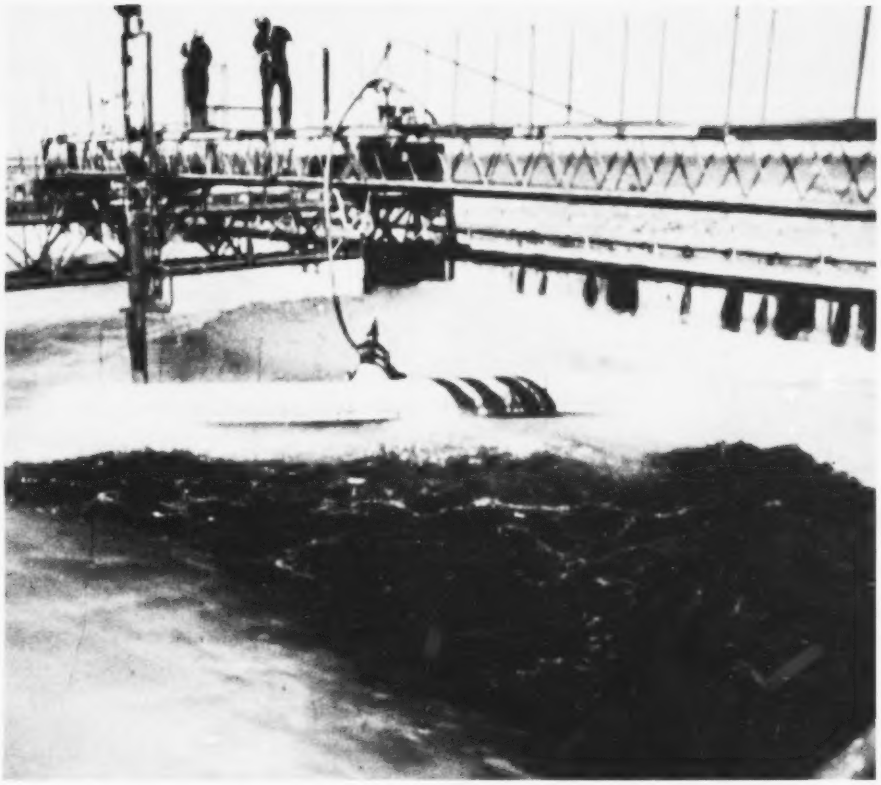
- eutrophication or overabundance of nutrients, which results in diminished levels of oxygen in shallow areas
- transport, fate, and effects of toxic substances.

Recent joint efforts between ORD and Canadian researchers directed at the problem of eutrophication have resulted in the development of a document outlining parameters of concern, present input levels, and projected effects of remedial efforts. Specifically, the research explored the use of simulation tools and mathematical models, established loading values, and estimated the extent of phosphorus reduction necessary to achieve desired water quality objectives.

As part of the attempt to define the total scope of the problem of toxic substances in the Great Lakes, a series of research objective strategy meetings, as well as a series of research needs exercises, have been scheduled jointly by American and Canadian environmental agencies. These coordinated activities are intended to set the stage for a concerted drive to control hazardous materials and toxic substances in the region.

In 1978, a major joint effort involved research into the atmospheric transport of both nutrients and toxic substances, providing the Great Lakes research community with data linking atmospheric conditions to water contamination. To date, the research has demonstrated that atmospheric transport of certain compounds can account for as much as one half of the total input of toxic substances to the Great Lakes system.

On-site testing of film-forming agents



Oil Spills

Such emergency support extends as well to clean-up guidance, and equipment and manpower assistance in the event of oil spills. There are approximately 10,000 spills per year (1970-76) accounting for a total annual spillage of over 15.6 million gallons. ORD has evolved a comprehensive oil spill control program. The National Oil and Hazardous Substances Pollution Contingency Plan, calling chiefly for the *physical* removal of the oil from the water, has provided the primary direction for this oil spill control research over the last decade.

However, in recent years ORD attention has also been focused on research into chemical agents and techniques for the control of oil spills. The program has been directed toward the development of standardized laboratory tests for evaluating the effectiveness and toxicity of commercially available products, particularly oil spill dispersants. As a result of this work, a number of new products have been identified by EPA and their low toxicity and high efficiency confirmed.

Dispersants

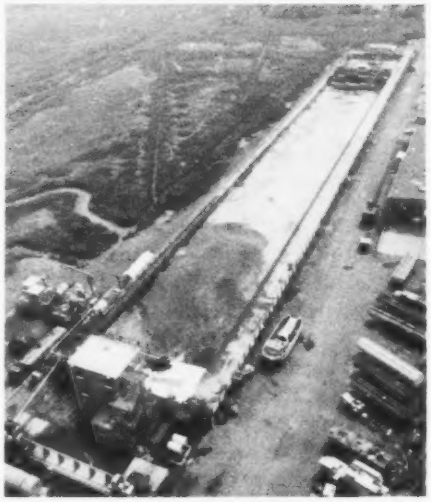
The oil and hazardous materials simulated environmental test tank is ORD's unique facility for the testing and development of devices and techniques for the control of oil and other hazardous spills. It was here that ORD evaluated a variety of dispersant application and mixing techniques.

A spray boom system for the application of dispersants was built, then tested, as were three separate field mixing techniques —methods by which the dispersant is blended into the spill to facilitate the dispersing action. The three mixing techniques tested were mixing boards, fire hoses, and boat bow and prop wash.

The Rockaway Spill

On July 31, 1978, a dredge sank off of Rockaway Inlet, New York, releasing thousands of gallons of fuel oil that resulted in the closure of five New York City beaches. On August 3, although the spill was considered a nonemergency (in that it presented neither threat of explosion nor fire), EPA approved the use of dispersants to protect the shoreline from further oil contamination. That same day ORD was called in to provide the technical expertise and the equipment necessary to disperse the oil.

A 32-foot Ports and Waterways vessel was selected as the platform for the dispersant application. Fire-fighting equipment on the vessel was modified to permit first the mixing of the dispersant with water, and then to permit it to be pumped onto the oil spill through either hand-held fire nozzles or a remotely controlled monitor. The operation began on August 4 and continued until August 8, at which time all New York City beaches were reopened.



EPA environmental test tank

Dispersant application at oil slick site

COAST GUARD 32318

Current Dispersant Research

An ORD-supported industry project to evaluate the effectiveness of dispersants in mitigating shoreline impacts from offshore spills was begun in October 1978, and will continue into 1979. The study involves the planned dumping of oil into the Atlantic Ocean, 30 miles off the coast of New Jersey. Each "spill" will be of approximately 400 gallons. Control spills, those not initially dispersed, and spills to which dispersants have been applied, will be evaluated and compared. Samples will be collected to measure the concentration of oil and dispersants in the water column, as well as to determine their biological impacts. The National Oceanic and Atmospheric Administration (NOAA) will assist with the assessment of the environmental effects of the dispersant on fish eggs, larvae, and plankton. NASA will perform remote sensing by aircraft, and the U.S. Coast Guard will furnish logistical support.

Film-Forming Chemical Agents

Traditionally, the action taken to protect the shoreline from offshore oil spills involves the placement of floating barriers or booms to direct the oil away from a specific area. Winds, currents, and waves, however, often wreak havoc with this booming effort and the result is shoreline contamination. Over the past few years, ORD has been studying film-forming chemical agents for use when these offshore methods fail.

A film-forming agent is sprayed on marshy, sandy, or rocky surfaces just before the oil slick arrives. The agent creates a chemical barrier or film, thereby preventing the oil from sticking to plants and rocks or penetrating the mud and sand. Then, by basically reversing the process that carried the oil onto the shore in the first place, low pressure water flushing washes the oil back into more open waters where it can be more readily collected and removed.

In 1978, ORD field-tested three natural and synthetic film-forming agents that previously performed well in the laboratory. Polyvinyl acetate (PVA), xanthan gum, and a flowing water film were evaluated under simulated spill conditions at Sewaren Beach, New Jersey. Both the PVA and the xanthan gum were chosen for their demonstrated staying power on plants and sand. The flowing water film, a thin sheet of water sprayed along the beach from a long, perforated pipe, was chosen because it was observed that oil appeared to adhere less freely to wetter surfaces than to drier ones. A light fuel oil, a waxy crude oil, and a tarry bunker oil were used for the spills.

Results of this research indicated the following:

- On the beach, PVA was the most durable and effective in preventing oil penetration.
- The flowing water film was also successful on the beach except where the water eroded channels into the sand and silt.
- On the beach, fuel oil most often penetrated the protective films.
- On the marsh, both PVA and xanthan gum prevented short-term oiling, especially of the fuel and crude oils.
- The flowing water film on the marsh proved less effective because a continuous film could not be maintained along marsh plants.
- On the marsh, bunker oil most often penetrated the protective films.

In the fall of 1978, polyvinyl alcohol—a film-forming agent—and a water-based oil spill dispersant were tested. Results of this study indicated that both agents applied to the beach ahead of the incoming oil slick effectively prevented oil penetration of the beach substrate when compared to an oiled, but chemically untreated, beach area.

Surface Collection

Surface collection agents work by forcing an incoming oil slick back on itself, ultimately to contract the spill into an area a fraction of its original size. In 1978 tests, such an agent worked effectively in calm seas, but in rougher seas it lost much of its ability to prevent oil from reaching the shoreline. When the turbulence was sufficient to break up the oil and mix it with the collecting agent, the mixture was nevertheless easily washed off of marsh plants.

Burning Agents

ORD research indicates that the introduction of chemical agents to burn away oil spills is not technically feasible except in a very few instances. In addition to the obvious air pollution problems created by such a technique, it is also difficult to initiate the burning of oil on water owing to the spreading and thinning of the slick, and to maintain the temperature necessary to sustain ignition.

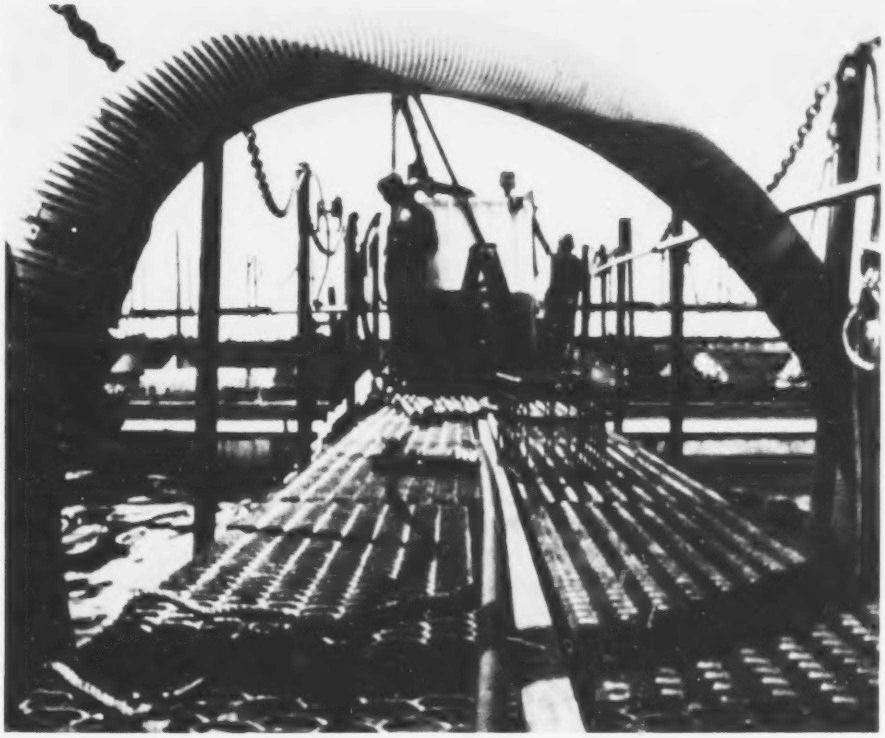
Sinking Agents

The sinking of oil is not considered environmentally acceptable, although the process occurs naturally under certain conditions. Sinking agents that facilitate this process are, however, prohibited by the National Oil and Hazardous Substances Pollution Contingency Plan; consequently they are not part of ORD's research.

Gelling Agents

Gelling of oil from a spill into a semi-rigid material to prevent spreading as well as to facilitate collection has the potential of being an attractive and environmentally sound process. No such gelling agent, however, is currently available in the U.S. To this end, ORD initiated research into the technical, economical, and environmental aspects of a new gelling technique involving the application of carbon dioxide and a gelling agent to renegade oil.

In 1978, laboratory and pilot testing demonstrated the technical feasibility of this method. Specifically, results of the tests indicated that even low vicosity oils such as Number 2 fuel oil could be gelled into a rigid mass. The gelled oil was readily removed from the water in the test tank by using nets and skimmers. Work is currently underway to develop a full-scale gelling agent application system.

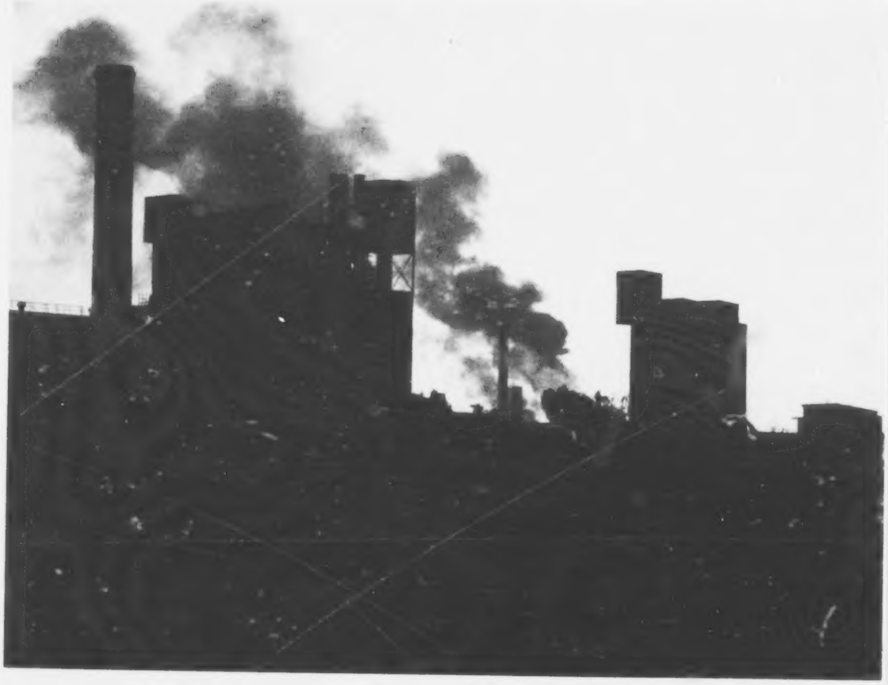


The following ORD components contributed to the research described above:

- Immediate Office of Assistant Administrator; Office of Health & Ecological Effects—Environmental Research Laboratory, Duluth; Health Effects Research Laboratory, Research Triangle Park; Office of Energy, Minerals and Industry—Industrial Environmental Research Laboratory, Research Triangle Park; Industrial Environmental Research Laboratory, Cincinnati (Edison, New Jersey) Office of Monitoring & Technical Support, Environmental Monitoring & Support Laboratory, Research Triangle Park; Environmental Monitoring and Support Laboratory, Las Vegas; Environmental Monitoring & Support Laboratory, Cincinnati

pollutant transport

ORD monitoring and analysis reveals fundamental transport phenomena



In 1978, a number of air pollution transport and monitoring studies were completed—some long-term, others short-term. New studies were initiated—older ones were continued. All serve to provide valuable information for the cities and regions involved. Additionally, much of the data amassed are important in the building of future studies and in EPA's ability to forecast long-range pollution effects through computer modeling and other sophisticated prediction techniques.

The Northeast Oxidant Transport Study

The Northeast Oxidant Transport Study was a 1978 EPA monitoring program to test and evaluate approaches for measuring ozone (and precursor) transport into an urban area. The purpose of the study was to aid states in their implementation plans for oxidant control. Also, the program represented the first phase of a multiyear study to gather data for an air quality computer model for use in the Philadelphia Air Quality Control Region.

Measurements of ozone, nitric oxide, nitrogen dioxide, total hydrocarbons, nonmetallic hydrocarbons, wind speed, wind direction, solar radiation, temperature, and vertical stability of the atmosphere were recorded at five ground-level monitoring network sites along the periphery of Philadelphia. In addition, ozone measurements at six supplemental sites were recorded, and a helicopter was used to collect airborne measurements of ozone, nitric oxide, nitrogen dioxide, and hydrocarbons and to record temperature and particulate light scattering in vertical and horizontal flight patterns upwind of Philadelphia. Early morning soundings of wind speed and wind direction were taken at three additional locations in support of the in-air operation.

Wide-Area Monitoring

A major study of regional air quality in 1978 was the wide-area monitoring program initiated in the Western Energy Resource Development Area (WERDA) to measure present pollutant concentrations and to follow future concentration trends. WERDA consists of eight Intermountain West and Northern Great Plains states containing large reserves of oil shale and coal to be developed in future years for power generation and other energy uses. (See Baseline Monitoring in the West in the "Monitoring Air Quality" section of this report.)

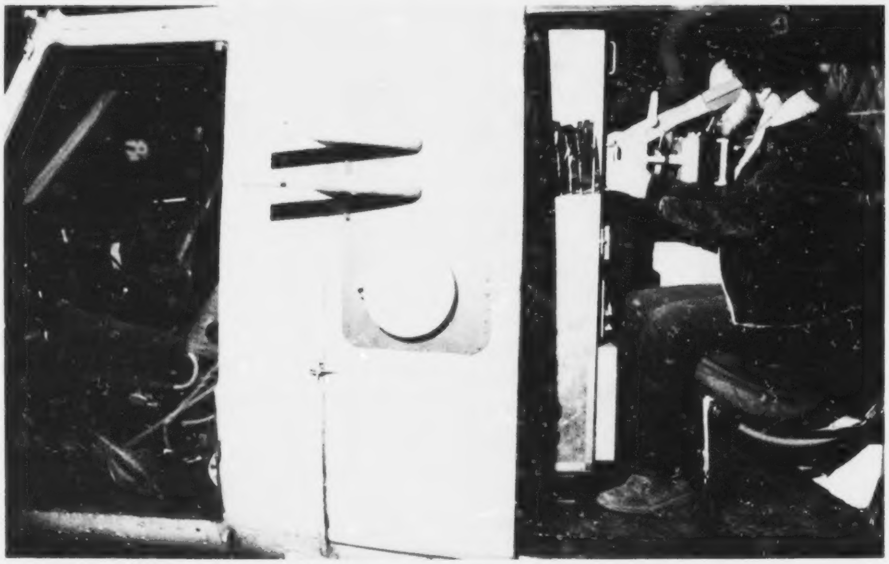
Airborne sampling and meteorological measurements and photographs were collected to provide sulfur dioxide, ozone, oxides of nitrogen, and particulate matter concentrations, as well as the temperature, dew point, altitude, air transport speed and location of these measured pollutants. This information was correlated with data from ground monitoring sites in the area, then combined with meteorological data for further analysis.

Twenty flights were made in southern Utah and northern Arizona where two general types of data were gathered. To establish a baseline of background pollutant concentrations, one set of flights was made to areas where no energy resources had been developed. The other flights were made in the vicinity of the Navajo Generating Station in Arizona and the Huntington Canyon Power Plant in Utah to determine their impact on air quality as far from the plant as measurable. Knowledge gained from these preliminary flights will be used to establish how far from a plant a plume can be measured, how much sampling is necessary to accurately measure trace elements, and how feasible it is to differentiate among plumes using such trace element analysis. Future flights will attempt to assess the impact of a number of pollution sources over a large area.

Houston Air Pollution Study

An extensive research effort was initiated in 1978 by ORD in the Houston area to investigate ambient ozone and haze problems. Using special Congressional appropriations, the study was in response to the concern expressed by the state of Texas that the EPA controls in that area might be ineffective.

Most of the effort of the study was concentrated in field studies performed over the summer. Significant assistance was received from local agencies and institutions. A report is expected by the middle of 1979.


Lidar equipment installed in a helicopter

Project MISTT

The Midwest Interstate Sulfur Transport and Transformation (MISTT) study, a 1975-1977 effort, provided clear evidence for the conversion in the atmosphere of sulfur dioxide (SO_2) from rural power plants to (secondary) sulfate and subsequent transport of this sulfate for up to 18 hours and over a distance of 300 km. Similar results were found for sulfates and ozone in urban plumes. Thus, this study demonstrated that pollution in one urban area may come from another urban area or from a rural power plant miles away. Air pollution control strategies must therefore begin to consider the long range transport of pollution across traditional political boundaries.

Regional Air Pollution Study

Toward the late 1960s EPA recognized the need for a comprehensive urban area study in which all processes affecting air pollutant emissions, dispersion, and composition as well as the atmosphere itself could be synergistically investigated. Specific focus for such a study was provided by a 1971 White House initiative calling for the development and validation of improved air quality simulation models from which least-cost pollution control strategies could be evolved.

Thus, in 1972 the Regional Air Pollution Study (RAPS) program was initiated, with the St. Louis Air Quality Control Region selected as the area for study. The major field measurement programs began in 1974 and were concluded in 1977.

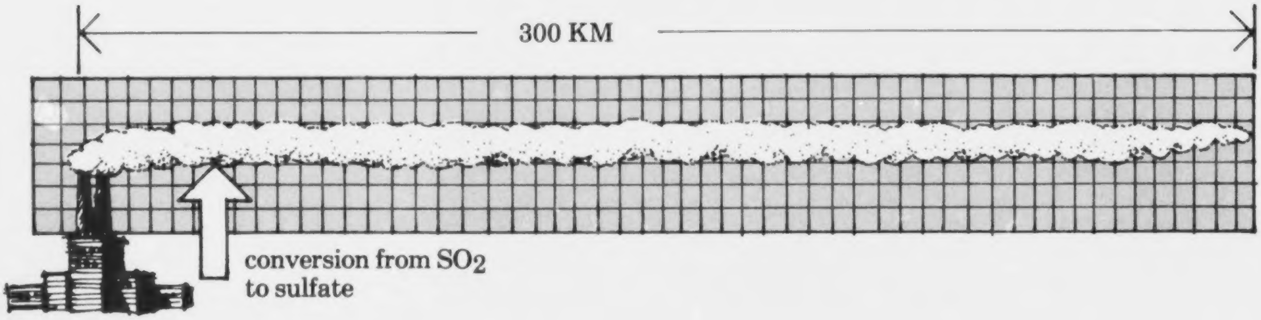
RAPS data, necessary for the establishment of an extensive information base from which to develop and validate models, were collected in a number of ways. The major routine data facility was the Regional Air Monitoring System (RAMS), 25 remotely operated stations recording pollutant concentration, meteorological measurements, and other key data. Routine upper air measurements were made at up to four sites of the upper air sounding network. Measured emissions were inventoried and their sources identified. These sources included stationary air pollution emitters (such as factories) as well as mobile sources, primarily automobiles.

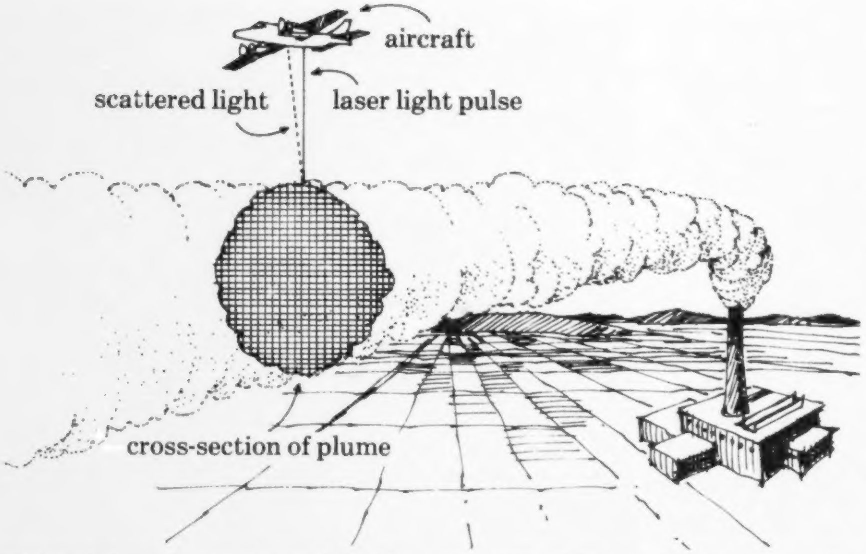
Additional non-routine measurements were generally obtained during intensive short-term field studies. Here, aircraft and helicopters from ORD's monitoring laboratory in Las Vegas, measured air structure and pollutant dispersion characteristics as well as pollutants and their precursors and other specialized measurements.

1978 RAPS Research

Completion of the field portion of RAPS provided EPA with the most comprehensive data base on emissions, meteorological parameters, and air quality measurements ever obtained for an Air Quality Control Region. Work in 1978 centered on selecting limited portions of these data for further analyses to determine relationships between emissions and ambient air quality.

A number of qualitative conclusions have already been reached. It has been





established, for example, that while the St. Louis Region is a major source of SO_2, local contributions to local sulfate levels are not very great, and that elevated sulfate values in the region are instead the result of slow-moving air masses from the Ohio and Tennessee River valleys. On the other hand, the larger regional occurrences of elevated ozone values appear to come from the entire eastern portion of the country although some measurable amounts can be attributed to St. Louis air pollution sources. In short, ozone is both a local and a regional problem.

Additional 1978 RAPS research included the evaluation of seven urban-scale air quality simulation models using the data gathered in the St. Louis study. Verification of these models is to be completed early in 1979.

Remote Sensing

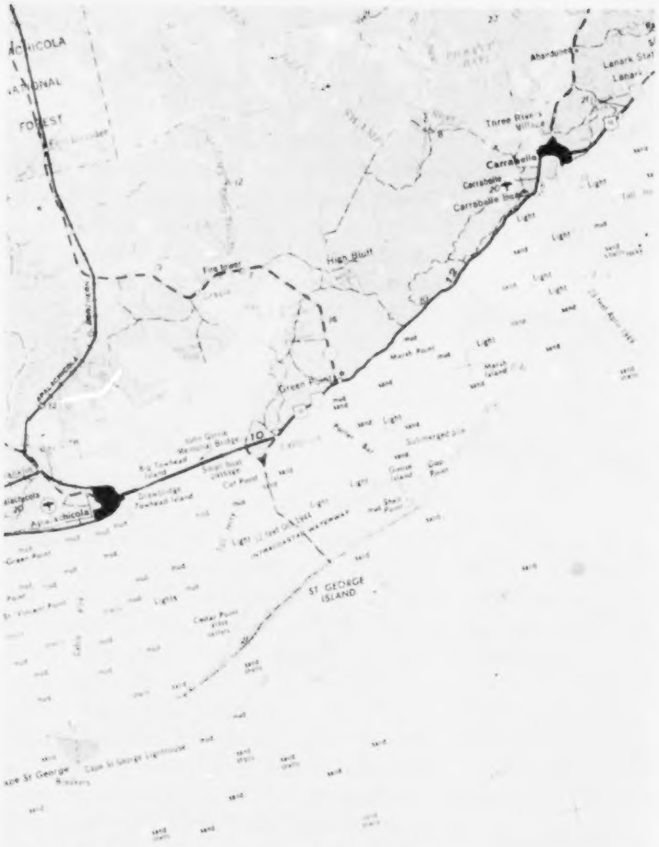
Through its remote sensing program EPA develops, tests, evaluates, and applies systems and strategies for monitoring the condition of the environment. Two advances in remote sensing technology over the past few years have been of particular significance to this program. First is the further development of automated computer processing techniques capable of translating data from aircraft or satellite into a graphic display of the features of the earth's surface. A second major advance has been the development of laser systems capable of mapping the distribution and concentration of specific pollutants in air and water.

In 1978, EPA continued work on the research and development of remote sensing technology. Considerable time was also given to the application of these technologies to the examination of specific environmental problems, with projects ranging from documenting the impact of forestry practices on water quality to characterizing the airborne transport of sulfates of power plant plumes.

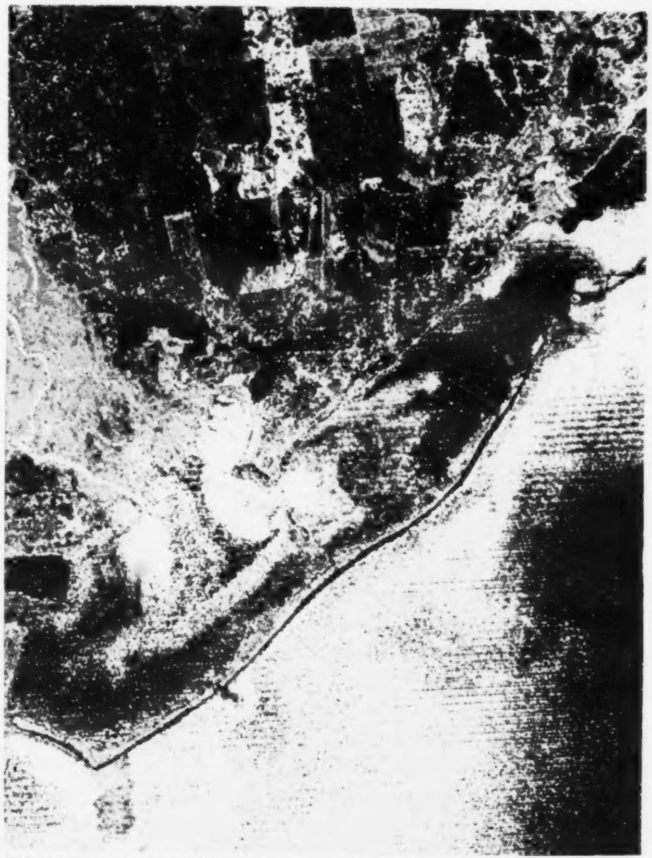
Development of airborne lidar (light detection and ranging) as a tool to monitor the long-range transport of air pollutants is being pursued by ORD. The instruments probe the atmosphere much in the same way a depth sounder probes water beneath a boat. A light pulse is emitted by a laser pointed toward the earth. Some light is scattered back to the aircraft and its on-board sensing and recording devices as the pulse travels through the atmosphere, striking air molecules and aerosols. The measurements provided by this technique, along with aircraft navigational information, can then indicate pollutant plume dimensions and location. The lidar system has a day/night capability.

During 1978, lidar was used in two studies: visibility impairment due to sulfur transport and transformation in the atmosphere (VISTTA) and sulfur transport and transformation in the environment (STATE). In these studies, lidar helped locate plumes and then position other aircraft carrying in-situ monitoring devices into the plumes. Lidar further was able to provide overall plume dimensions, allowing in-situ measurements to then be accurately extrapolated to the entire plume. Subsequent computer processing of lidar information was also used to determine the intensity of aerosol concentrations within the plume.

A third generation lidar system is currently being tested. This advanced lidar will have increased vertical and horizontal accuracy and will be capable of distinguishing among plumes with different particle size distributions.



MAP OF APALACHICOLA BAY



ENVIRO-MAP OF APALACHICOLA BAY

Additional Laser Technology

A second type of airborne laser remote sensor currently under development is the earth-reflected differential absorbtion monitor. This device will be capable of extremely accurate measurement of the air column content of ozone beneath an aircraft. Prototype testing suggests a sensitivity of 8 ppb ozone (if uniformly distributed) in a column 1-km thick, a sensitivity sufficiently adequate to monitor ambient ozone and track urban plumes to study oxidant transport. Other applications of the system indicate potential usefulness in detecting and monitoring both urban oxidant plumes and regional ozone pollution.

An airborne laser fluorosensing device to survey water pollution problems is also under development in both field and laboratory studies. This device will be able to indicate nutrient pollution sources and describe pollutant transport by mapping the path of chlorophyll concentration patterns in water. Additionally, the fluorosensing system will be able to map fluorescent dyes released into waterways for tracer studies, and, with modification, be capable of monitoring total organic carbon in surface waters.

Enviro-map

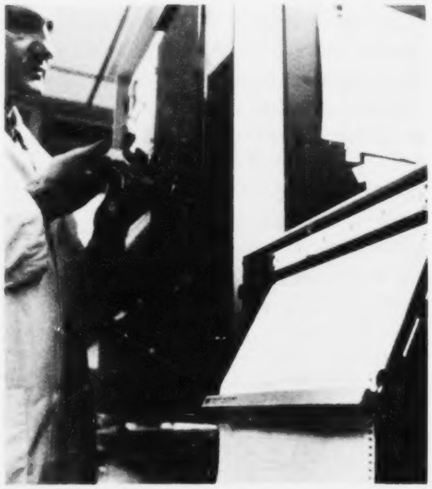
Enviro-map is an analytical aid to environmental studies. The system is capable of reading and processing a broad variety of information fed to it from remote sensing sources such as multispectral scanner sensors or satellites as well as from ground collection systems. Additionally, enviro-map can process the remote sensory data in conjunction with all manner of geographical data, demographical and environmental statistics and mathematical models. It affords EPA the ability to conduct complex environmental assessments and impact studies, and to delineate and classify environmental conditions.

The enviro-map system hardware consists of a computer, a TV screen for information and a two-dimensional image, and corresponding video tape recording devices. Enviro-map software, the computer programs, were developed in 1978 to convert existing pictorial, photographic, map, and numerical information to digitized data on magnetic tapes. These data were then processed to classify the information into a universal reference system to facilitate both storage and retrieval.

Actual use of this enviro-map data base and system hardware allows an analyst to produce, on the TV monitor, visual representations of geographical and environmental conditions in a given area at a given period of time. Of even greater value, any changes in condition, either actual or hypothetical, can also be visually represented by summoning geographical overlays and other pertinent information from the data base.

In a basic application of the enviro-map system, a computer-constructed picture of the lower Apalachicola River Basin and Apalachicola Bay, Florida, was used to anticipate the effect of forestry practices on bay fisheries and water quality. Different colors obtained by processing satellite multispectral scanner data indicate the patterns of different forestry practices and stages, while bay color patterns describe water turbidity and acidity impacts from erosion associated with these practices. Similar pictures for the same area at different times showed water conditions as they were affected by tidal flows and changes in the pattern of logging.

In 1979, enviro-map assessments will be made for strip coal mining areas in the West and in other regions of major environmental concern.



Data processing in support of ion chromatography

Ion Chromatography

Ion chromatography is a relatively new analytical technique that allows the assay of many pollutants that in the past have been extremely difficult to analyze, such as sulfate, nitrate, and ammonium ions. In addition, certain gaseous pollutants such as SO_2, collected as sulfate, can now be assayed with the ion chromatograph.

Ion chromatography is the successful combination of two analytical techniques known as ion exchange chromatography and conductivity detection. In ion exchange chromatography a solution is passed through a polymer containing acidic or basic groups that react with the ions of the solution. Ions of specific compounds are thus separated by the reactions with the polymer. Then, measurements of the resulting reaction products can be used to determine the types and concentrations of compounds in the original solution. But this method, that evolved in the 1940's, never reached its full potential as an analytical tool because of the lack of a universal detector to apply to the reaction products. That is, a detector was needed that measures all ions. One method that was often applied was conductivity detection, a measurement of ions by detecting the presence of their conduction properties. However, conductivity detection also met with limited success because of the high background interference produced by a required working fluid, known as an eluent, that washes the ionic reaction products from the polymer.

In 1975, research by industry developed a method to suppress the eluent thereby reducing the background interference and making the development of ion chromatography a reality. The success of the eluent suppression method now allows for the effective use of ion chromatography for the analysis of a vast number of inorganic and organic compounds. Furthermore, ion chromatography provides the scientific community with a single, sensitive and selective tool, capable of the precise measurement of compounds formerly analyzed by several different techniques with relatively poor selectivity.

The widespread application of ion chromatography by both government agencies and commercial laboratories was primarily the result of research carried out by the EPA's environmental science laboratory.

In 1978, ORD sponsored a national symposium on the ion chromatography analysis of environmental pollutants. Attendance by more than 200 scientists from around the world testifies to the significance and rapid growth of ion chromatography as an analytical tool for environmental pollutants.

Mussel Watch

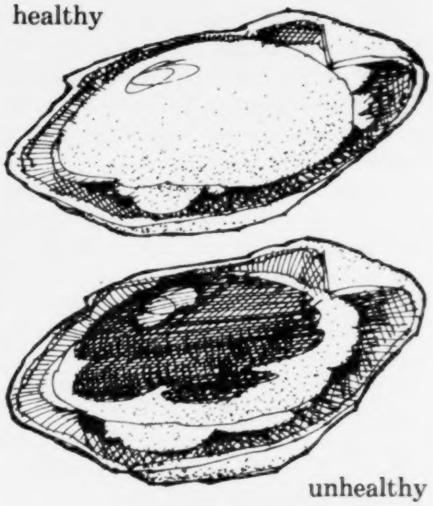
Many of the pollutants introduced into coastal waters are present in amounts so small that they are not readily analyzed from seawater samples. However, mussels and oysters, it was found, concentrate most pollutants to easily measured amounts, and were therefore chosen as the subjects of a pilot ORD program called mussel watch, a study that began in 1976 and that was steadily expanded until it covered 106 locations by 1978.

The specific purpose of mussel watch was to derive an accurate measure of heavy metals, halogenated hydrocarbons, petroleum hydrocarbons, and transuranic radionucleides in U.S. coastal waters. Annual collections of the mollusks were made at 106 stations on the Atlantic, Gulf, and Pacific coasts. Monthly samples were taken on the Atlantic and Pacific coasts for evaluation of seasonal differences. Five participating laboratories worked to analyze the samples.

Initial results of the study showed that there were no significant seasonal variations in the heavy metal contents in mussels from either the Atlantic or Pacific coasts, and that no markedly elevated levels of metals were found in any station from the three coastal areas.

However, extremely high levels of DDD and DDE residues were measured in mussels collected in the San Pedro-Los Angeles area, and elevated amounts were observed in mussels collected between San Francisco and San Diego. The Pacific Northwest and Atlantic coast mollusks, on the other hand, contained low amounts of DDT derivatives.

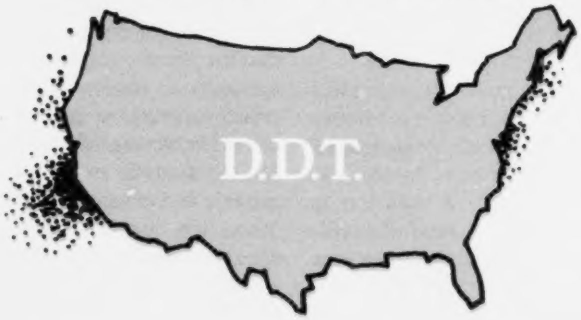
Large amounts of polychlorinated biphenyls (PCBs) were mesured in animals in stations from San Diego to San Francisco on the West Coast, and on the East Coast elevated amounts of PCB were found in stations from Florida to Boston, especially those in the highly industrialized areas of the Northeast. Petroleum hydrocarbons were observed in four samples; three from the Gulf Coast and one in Washington state.



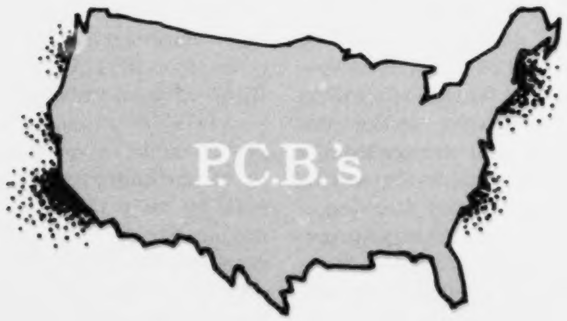
Samples taken in 1978 are currently being analyzed. Additional studies are underway to facilitate use of the data gathered in the mussel watch program. The data are being readied for easier use by more clearly defining the pertinent physical, chemical, and biological effects from pollutant uptake by bivalve mollusks.

As an example, a 75% reduction in growth potential of **Mytilus edulis**, a blue-black bivalve, has been related to elevated levels of pollutants present in the tissues of field-exposed **Mytilus.** With the use of mussel watch data to relate such specific physiological impacts to pollutant concentrations found in specimen tissues, the program takes on yet greater dimension, serving as a tool for resource evaluation and management, in addition to its primary function as a measure of pollutant transport.

DDT MEASURED IN MOLLUSKS



PCB's MEASURED IN MOLLUSKS



The following ORD components contributed to the research described above:

- Office of Monitoring and Technical Support—Headquarters; Office of Monitoring and Technical Support—Environmental Monitoring and Support Laboratory, Las Vegas: Office of Air, Land & Water Use—Environmental Sciences Research Laboratory, Research Triangle Park; Office of Health & Ecological Effects—Environmental Research Laboratory, Narragansett

nitrogen oxides

Technology development by ORD will help reduce future NO_X emissions

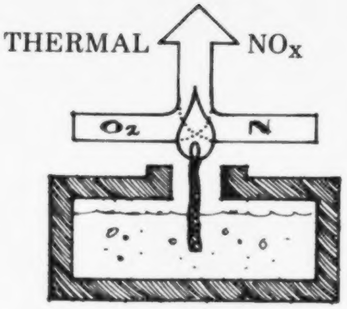
Damage to the ozone layer, photochemical smog, high nitrate rainfall. Today's scientific data suggests that nitrogen oxides (NO_X), principally nitric oxide (NO) and nitrogen dioxide (NO_2), are among the most significant contributors to such degradation in air quality. This degradation is not only aesthetically offensive but may be health- and even life-threatening.

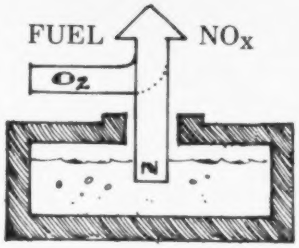
The high concentrations of these NO_X emissions are the result of human acitivity. In 1974 it was estimated that these technology-associated pollutants were produced at a rate of 23 million tons annually. Ninety-nine percent of these emissions originated from fuel combustion, with approximately half coming from stationary sources such as boilers and the other half from mobile sources such as automobiles. By 1985, however, with the continued growth in energy use and increased reliance on coal as fuel, EPA anticipates a 70%/30% split of stationary to mobile NO_X polluters. By the year 2000, in the absence of stricter emissions standards, this trend could mean a NO_X output that is 200-300% higher than present levels.

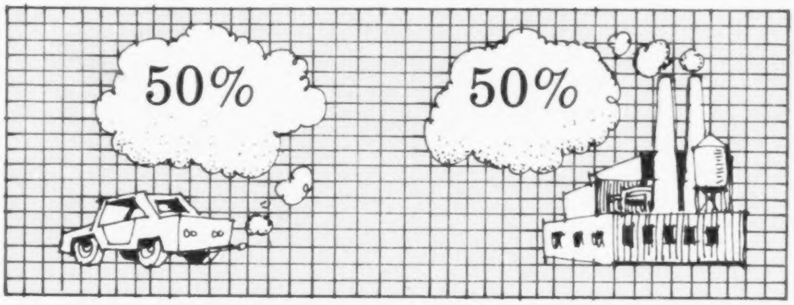
NO_x Control

The EPA NO_x control program is aimed primarily at developing combustion modification technology that would reduce NO_x emissions without increasing other potentially harmful emissions, or reducing energy systems operability and efficiency. Initially such study involves understanding the mechanisms by which NO_x and other pollutants are formed and destroyed within a combustion area or flame zone.

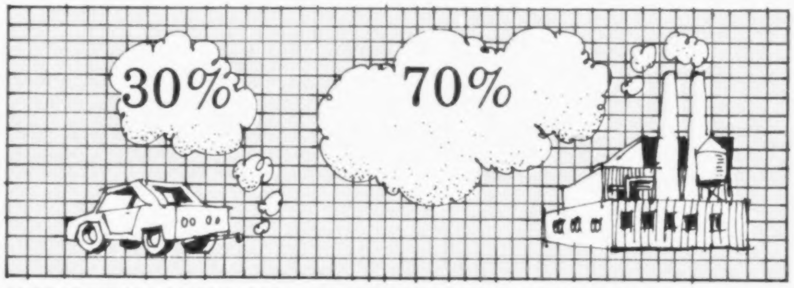
Nitric oxide is formed in one of two ways, depending on the fuel characteristics and the chemical reactions in the combustion. Thermal NO is formed by the oxidation of nitrogen in the combustion air; its formation strongly depends on the amount of heat available and can be controlled by reducing peak flame temperature. Fuel NO and NO_2, on the other hand, are formed by the oxidation of nitrogen chemically bound in the fuel. This reaction weakly depends on temperature, but strongly depends on the amount of oxygen available and can, therefore, be controlled by limiting the oxygen availability in the flame zone.







1974 NO_x EMISSION BREAKDOWN



1985 ESTIMATED NO_x EMISSION BREAKDOWN

Low NO_x Burner Program

A variety of projects were undertaken by ORD in 1978 to study and develop low NO_x burners for utility and industrial boilers. The low NO_x burner program mirrors EPA's general NO_x control goals with the more specific aim of reducing uncontrolled NO_x emissions by 80%.

Under this program, an advanced low NO_x coal burner has been developed based on the proven principle of staged combustion techniques already in use for NO_x control. The burner design involves the use of three concentric combustion zones. A fuel-rich primary zone is both low in heat and oxygen, thereby minimizing thermal and fuel-generated NO. Additional oxygen is then permitted in the secondary and tertiary zones, allowing for high combustion efficiency, equivalent to or better than that in existing coal burners.

Such a design would be compatible with new coal-fired utility and industrial boilers, boilers converting from gas and oil to coal for fuel, and can also be retrofitted to existing boilers.

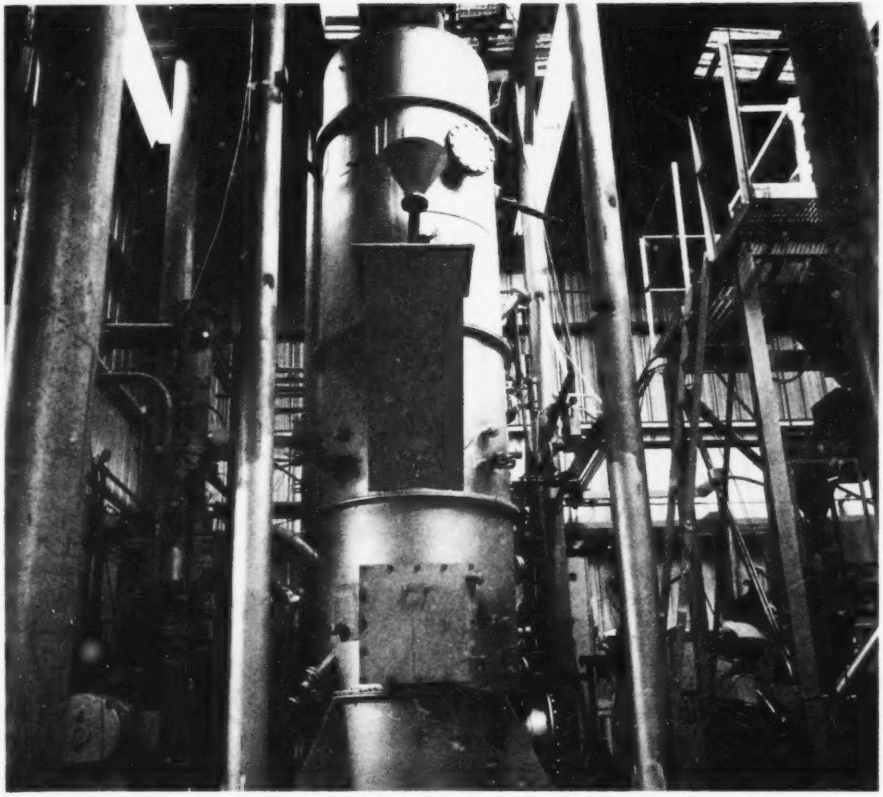
In 1978, the advanced low NO_x burner was tested on an experimental scale of 15 to 20 MW and consistently produced NO_x emissions below 150 ppm, a decrease in emissions of as much as 85% over conventional burners of this size. Also, as the burner size was increased, the NO_x emissions decreased. These results set an encouraging trend toward the commercial application of the technology.

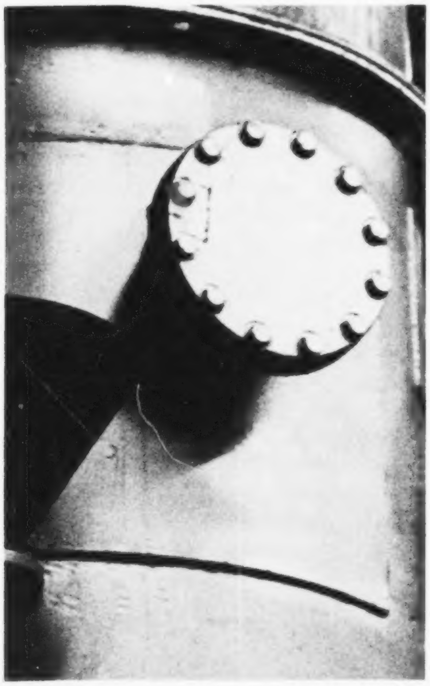
Two projects have also been initiated for field evaluation of low NO_x burners: a test using two industrial boilers in the range of 30 to 150 thermal MW, and a test involving two utility boilers in the range of 100 to 300 electric MW. The projects were begun in late 1978 and are to be completed in 1982. Project goals are to demonstrate that:

- NO_x emissions below 150 ppm are possible in practical boilers.
- Low NO_x emissions can be achieved without increased soot emissions.
- Thermal efficiency of the boiler is equal to or better than that of the baseline boiler.
- Burner design with low NO_x modifications does not increase corrosion in the boilers.

A unique feature of this program is that these development and demonstration studies, while managed by ORD, are coordinated by two panels of experts drawn from the business world, research institutions, and government. A technical review panel composed of representatives of boiler manufacturers, utilities, and research organizations provides a continuing evaluation of the program as it relates to practical systems. A technology transfer panel composed of governmental agencies and trade association members reviews the program's objectives with respect to national, state, and industry goals.

Utility boiler at test facility





Residential Furnaces

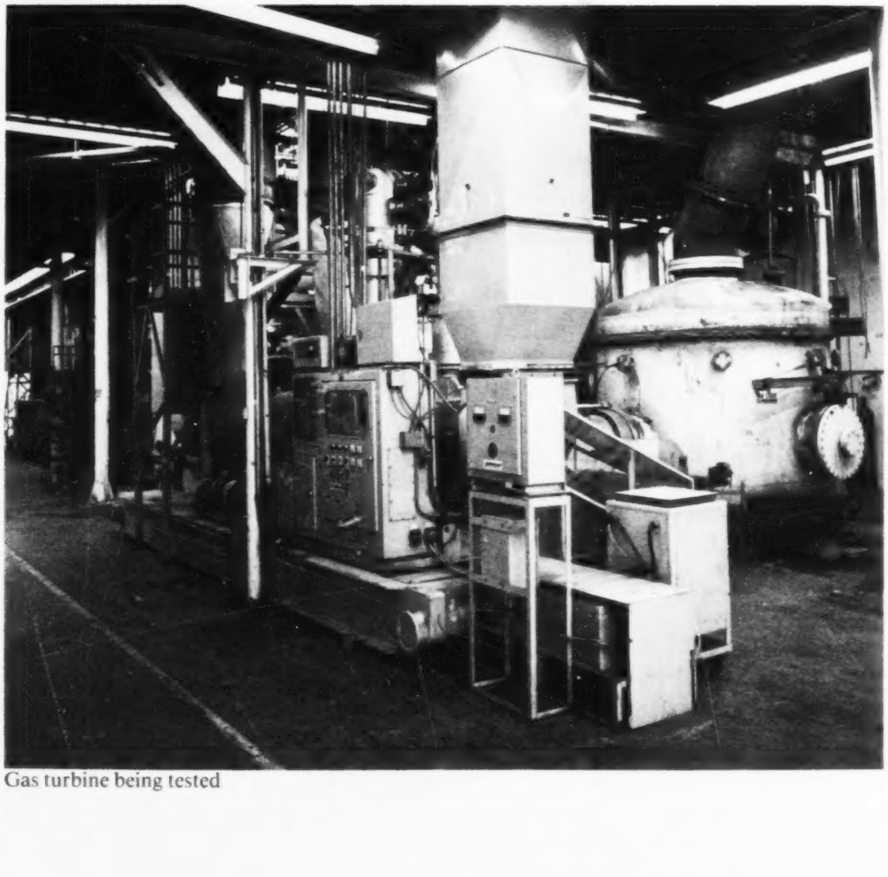
Residential furnaces emit pollutants near ground level in populated areas during a limited period of the year. In doing so, a significant amount of energy is consumed, almost exclusively through the use of clean fuels such as gas or light oils. Owing to the large number of these furnaces and the fixed flow of fuel and air in them, controls are difficult to evolve.

In 1977-78, however, EPA developed an integrated residential oil furnace. This furnace, designed "from scratch," to minimize both pollution and fuel consumption,was tested in six residences over one complete heating cycle. Its performance met or exceeded EPA emissions goals for the study and its operation consumed an average of 18.5% less fuel than the existing furnaces.

Gas Turbines

Current gas turbines use a combustion mode similar in principle to that found in boilers but different in practice because of very high temperatures and pressures. These turbines use natural gas and light oils for fuels, and although NO_X emissions are high, they can be controlled using a water injection technique. However, in the future, there appears to be a trend toward the use of heavier liquid fuels, with significant concentrations of fuel nitrogen, which are expected to be resistant to control by water injection.

Anticipating the need for a new control technology, a program was initiated by ORD to develop a dry control technique that is expected to be effective in the reduction of both thermal and fuel NO from stationary gas turbines using heavy liquid fuels. In 1978, evaluation of a number of combustion concepts was completed and a combustion design was developed that was capable of exceeding program goals. Currently, the successful concept is being scaled up to the size appropriate for laboratory evaluation. Following completion of tests, the combustion technology will be incorporated into a practical gas turbine engine for evaluation on a test stand.



Gas turbine being tested

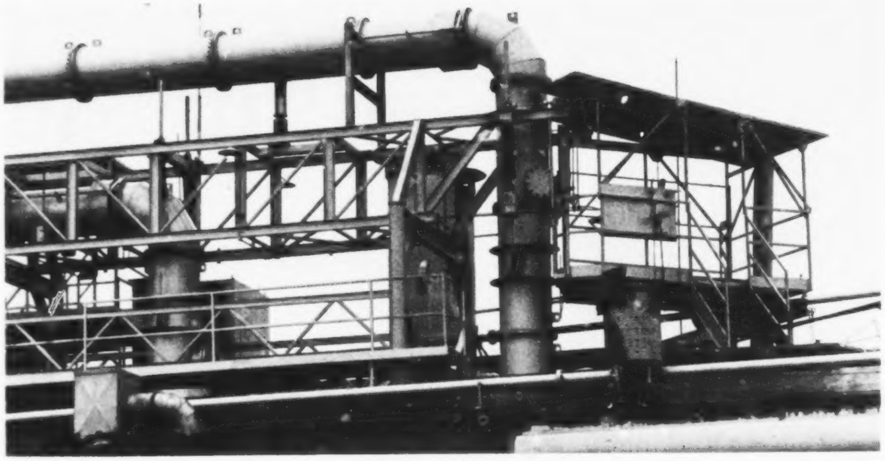
Advanced Processes

ORD's advanced process program is directed toward developing advanced technology capable of significant emission reductions over existing state-of-the-art control technologies. Both the low NO_X coal burner and the integrated residential furnace concepts originated in this research area. The general approach used in this program is one of experimenting with a number of different systems to develop a technology for low emissions combustion of a specific fuel.

One advanced concept that appears capable of achieving very low pollutant levels in clean gaseous and vaporizable liquid fuels is catalytic combustion. Here, a catalyst is used in place of a burner to initiate the major energy release. The fuel is oxidized and releases its heat within the channels of the catalyst bed. Only very short residence times are needed for complete combustion and there can be very high volumetric heat release rates.

The process, developed in 1978, is currently limited by the temperature at which the catalyst itself degrades, and the "kinetic threshold" temperature above which the rate of NO_x production becomes significant. Thus, new system designs must be evolved to achieve longer catalyst life and higher thermal efficiency.

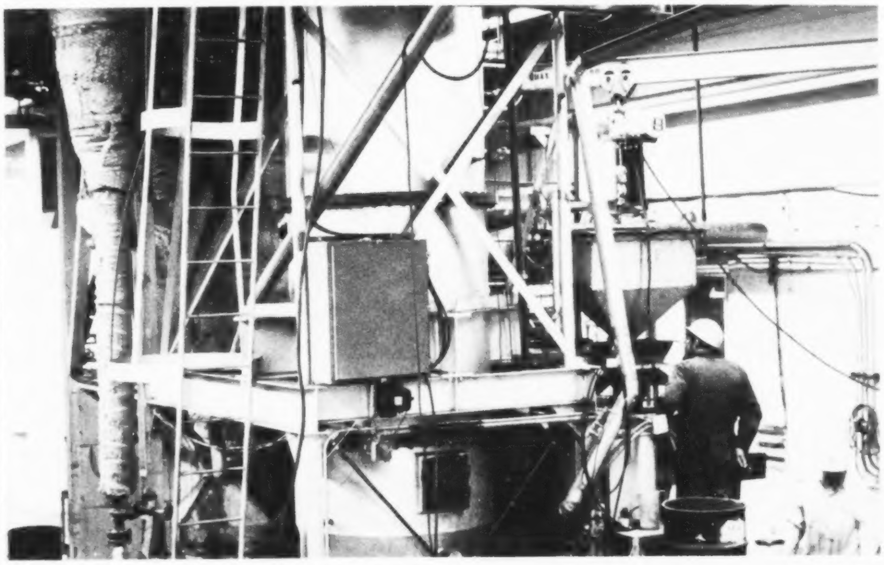
Three such systems concepts are currently being tested on a laboratory scale. The first is an ultra-lean fuel to air ratio combustion mode similar to that used in gas turbines. At combustion conditions typical of gas turbines, very low NO_x levels (below 10 ppm) have been observed, along with low emissions of carbon monoxide and hydrocarbons.



A second concept with potential application to boilers has produced similarly low emissions levels, while operating on natural gas. The third concept is a catalytic staged combustion which controls fuel nitrogen conversion to low levels (for NH_3-containing gaseous fuels).

While all three concepts require further development and evaluation before practical systems can be designed, catalytic combustion appears, at least, to have the potential to serve as the basis for second generation combustion systems with near-zero pollutant emissions.

Commercial boiler undergoing testing



The following ORD components contributed to the research described above:

- Office of Energy, Minerals, & Industry—Industrial Environmental Research Laboratory, Research Triangle Park

sulfur sludge

ORD tests and evaluations help reduce by-products of sulfur control technology

Today, sulfur dioxide (SO_2) emissions from new coal-fired utility boilers are generally controlled by exposing the boiler exhaust to a lime or limestone slurry which, by chemical reaction, absorbs the sulfur from the gas. This chemical reaction process, known as "scrubbing", creates a calcium sulfite sludge that is the product of the chemically transformed lime and sulfur. The remaining scrubbed exhaust, in the meanwhile, travels up a flue and is released into the atmosphere. This flue gas desulfurization (FGD) process using either lime or limestone as the scrubbing agent is the method being used by over 90% of U.S. utilities to meet SO_2 emissions standards for new coal-burning plants.

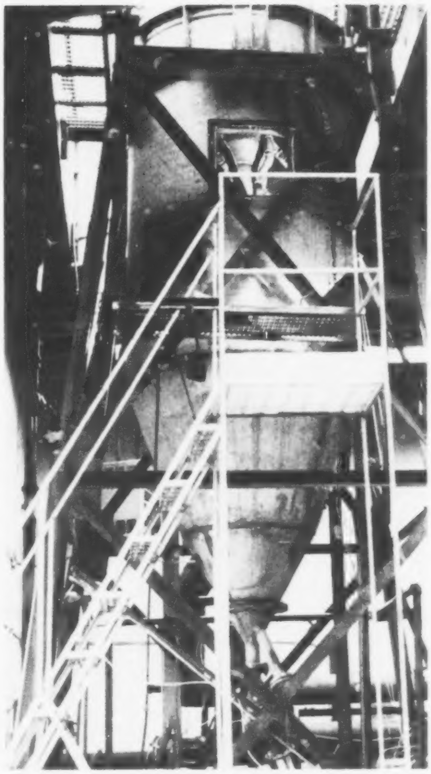
It is expected that such lime/limestone systems will be a part of most projected boiler construction over the next 10-15 years, ultimately representing an overall investment of several billion dollars in SO_2 control technology. It is a major ORD concern then that such monies be spent as wisely as possible and with the greatest benefit to the environment.

Forced Oxidation

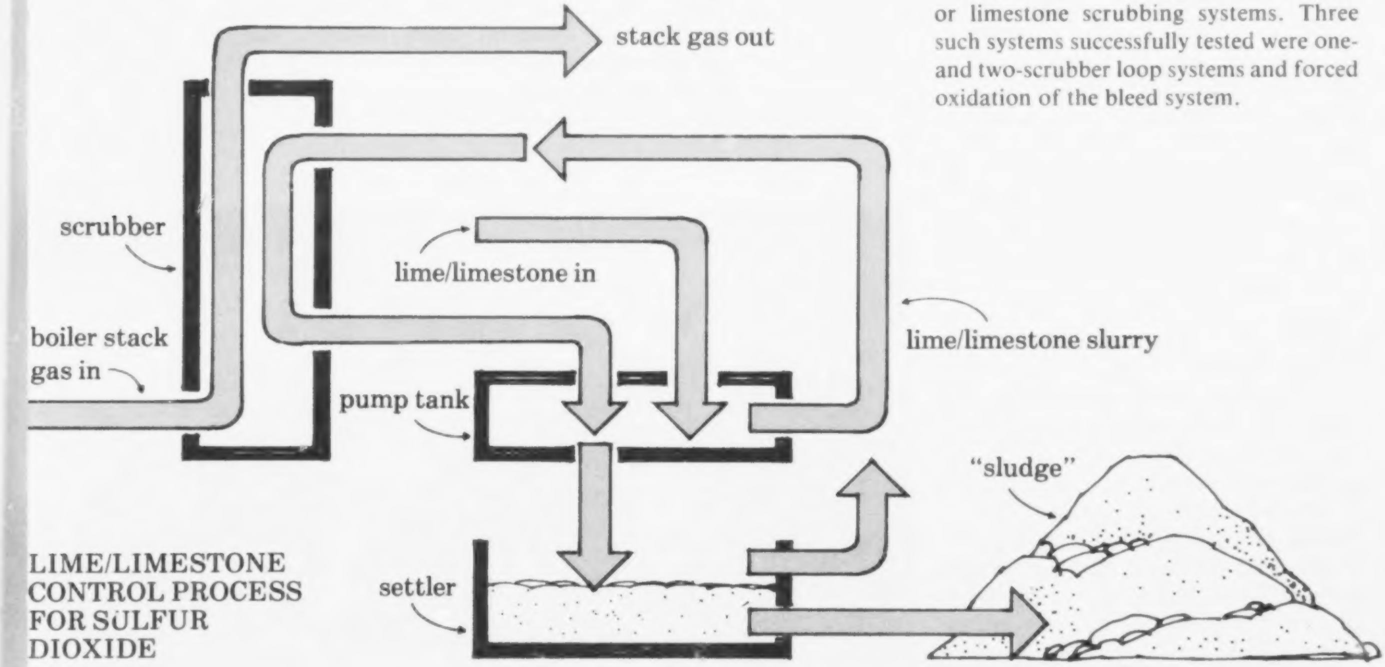
A key problem posed by the lime/limestone FGD process is the disposal of the quicksand-like waste solid or calcium sulfite sludge that remains following the SO_2 lime/limestone reaction. Currently, the sludge is disposed of in ponds that are lined to prevent seepage into the water table, a process that can account for up to 25% of the overall scrubbing cost. These ponds also require large areas of not readily reclaimable land, a major concern in areas where such acreage is simply not available.

In Japan, where land availability is a major problem, the sludge is modified during the scrubbing by exposing it to air forced in under high pressure. This forced oxidation technique converts the calcium sulfite sludge to calcium sulfate or high purity gypsum, to be used in various manufacturing processes. Unlike Japan, however, the U.S. suffers no shortage of gypsum, and thus the high equipment and operating costs of forced oxidation cannot be justified.

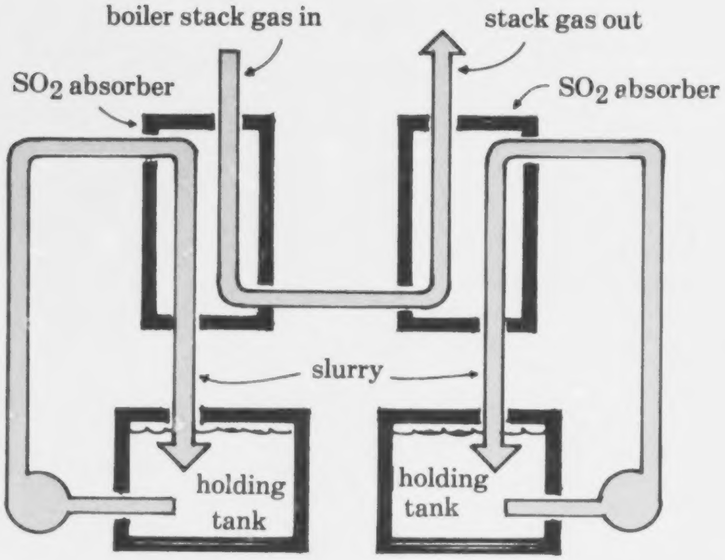
Still, both environmental and economic factors point to the need to somehow reduce the quantity of sludge produced while also improving its quality and its potential for positive use. To this end, current ORD-sponsored studies at the Tennessee Valley Authority (TVA) Shawnee Steam Plant are examining the use of far less costly forced oxidation processes that create a low purity gypsum ideal for use as landfill. Here, the calcium sulfite sludge is exposed to air at normal atmospheric pressure to facilitate the chemical reaction necessary to produce the low purity gypsum. The resulting product occupies 30%-50% less volume than sulfite sludge, is more soil-like, and is more readily dewatered. Compared with other recent methods of improved sludge disposal studied, the forced oxidation technique appears to be only one-third as costly, as well as allowing land being used for fill to eventually be reclaimed for other uses. There is also the indication that future testing could reduce these costs to below those of the currently popular ponding method.



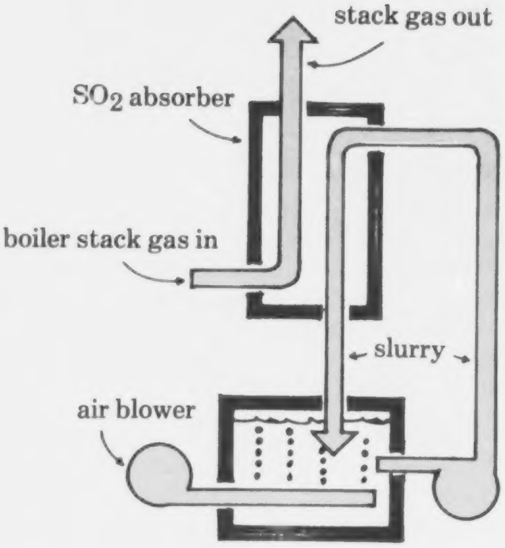
Over the past two years ORD research has demonstrated that simple forced oxidation can be easily incorporated into a variety of new or existing commercial lime or limestone scrubbing systems. Three such systems successfully tested were one- and two-scrubber loop systems and forced oxidation of the bleed system.



LIME/LIMESTONE CONTROL PROCESS FOR SULFUR DIOXIDE



DOUBLE LOOP SCRUBBER



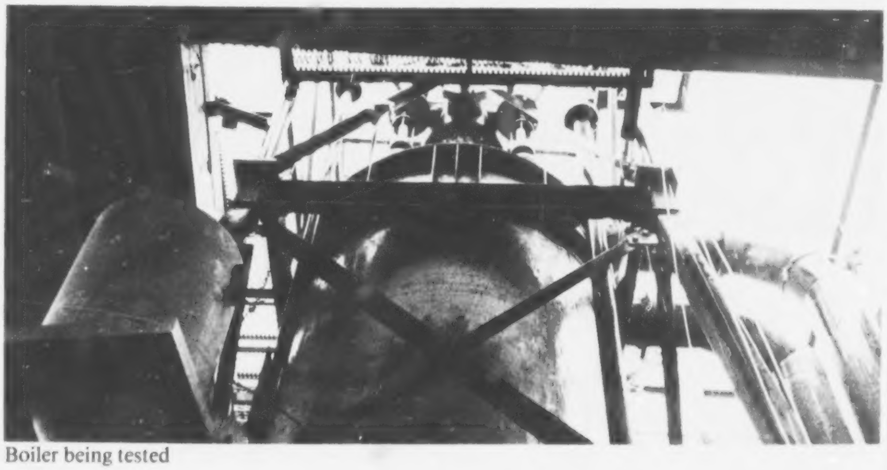
SINGLE LOOP SCRUBBER

The two scrubber loop system—the most complex tested—involves two separate exposures of the exhaust gases to sulfur absorbing liquids: one loop is for sulfur dioxide removal, the other is for maximum oxidation efficiency. Tests of this system indicated that SO_2 removal efficiency is increased and utilization of the lime or limestone is maximized, which in turn decreases sludge volume. Also, forced oxidation using the double loop system allows for the highly efficient use of less expensive, less energy intensive limestone rather than lime as a scrubbing agent. This savings is expected to outweigh the higher costs of the construction and operation of the double loop system.

The single loop system tests also indicated a more efficient removal of sulfur dioxide when forced oxidation is used. However, this system, designed to work only with limestone, does not provide for the maximum use of this scrubbing agent, and, therefore, while sludge quality is upgraded, sludge volume remains roughly the same as without forced oxidation. Nevertheless, the majority of existing and planned commercial limestone FGD installations use the single loop system, one which allows for easy modification to include forced oxidation into the total process.

Conceptually, the ideal system for commercial installations would involve forcing oxidation of the sludge in a small bleed stream, (by tapping into the main slurry flow), rather than having to circulate the air through the entire sludge mass, as is necessary in the double and single loop systems. Results of ORD testing of the forced oxidation of the bleed stream, however, have met with minimum success. Oxidation rates were too low and the resulting sludge did not dewater or handle appreciably better than unoxidized sludge.

However, a 1978 study conducted at the Shawnee test site indicated that the bleed stream system could, in fact, be made to work, and work as efficiently and less expensively than forced oxidation in either the double or single loop systems. What was necessary, according to preliminary study findings, was the use of certain chemicals added to the lime/limestone slurry.



Boiler being tested

Scrubber Additives

The use of additives to improve SO_2 removal efficiency has been a focus of ORD research. Better SO_2 removal would allow implementation of the more stringent New Source Performance Standards as well as reduce the cost of FGD through:

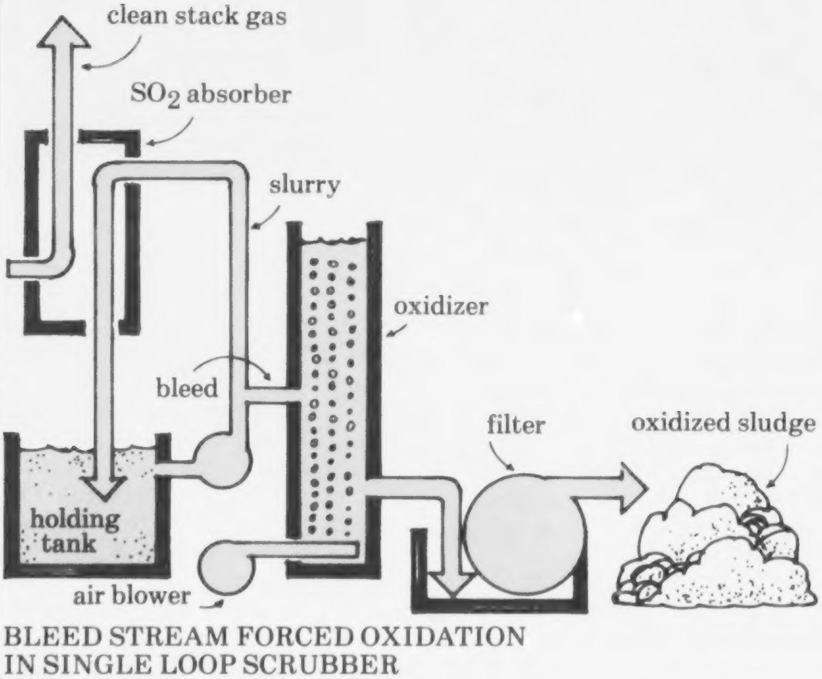
- substitution of limestone slurry for more expensive lime
- reduction of the amount of slurry required to react with the gas to form a solution—e.g., smaller tanks
- reduction of limestone feed requirements
- reduction of the amount of sludge produced.

Experiments carried out at the Shawnee test facility have demonstrated the effectiveness of two chemical additives—magnesium oxide and adipic acid—in SO_2 removal efficiency.

Magnesium Oxide

When magnesium oxide (MgO), an inexpensive solid, is added to the slurry, the rate of SO_2 transfer from gas to liquid is boosted considerably along with a marked increase in SO_2 removal efficiency. Shawnee test results on double loop systems, for example, have indicated 90% SO_2 removal with MgO versus 80% removal without. And a single loop system with MgO can achieve 85% removal, twice its efficiency without additives. The amount of slurry necessary to produce efficient removal is also diminished with the use of additives. Where formerly 65 gallons of lime slurry per thousand cubic feet of flue gas were needed to produce 90% removal efficiency, with MgO the figure drops to 37 gallons per thousand cubic feet. Thus, the need for less slurry allows the use of smaller tanks and less power for pumping the slurry.

The principal difficulty with MgO has been with the sulfite-magnesium sludge it creates—it is slow to settle, difficult to dewater. However, 1978 ORD tests indicated that by using MgO in the commercially-popular single loop scrubber system along with forced oxidation of the bleed stream, a calcium sulfate sludge is created that is both fast settling and easily filtered.



BLEED STREAM FORCED OXIDATION
IN SINGLE LOOP SCRUBBER

Adipic Acid

Although adipic acid, a water soluble nontoxic industrial chemical, is more expensive than MgO, its effectiveness in smaller concentrations makes it less costly as a scrubber additive. Additionally, ORD test results show that it enhances the gas-to-liquid transfer, improves SO_2 removal efficiency, and maximizes limestone utilization—meaning less feed, less waste, greater operating reliability.

Research done in 1978 shows adipic acid also particularly adaptable to single loop scrubbing where forced oxidation can take place in a holding tank. This configuration is the simplest of the various tested alternatives for simultaneously improving SO_2 removal by the use of additives, and improving sludge quality through forced oxidation. Furthermore, adipic acid, unlike MgO, is also efficient in the scrubbing of exhaust from boilers that use high chloride coal.

Conclusions

Whichever additive is finally used, two general conclusions can be drawn from 1978 ORD FGD research. First, the use of additives in scrubbing systems will significantly lower the amount of energy required to bring about high efficiency SO_2 removal. This stems from the ability of the additive to help achieve a rapid gas-to-liquid transfer, and from the effective use of limestone rather than energy-intensive lime as a scrubbing agent. Second, the use of additives in conjunction with forced oxidation in scrubbing systems will greatly enhance the efficiency of the total FGD system; reducing the costs of materials, reducing the costs of sludge removal, and increasing the quality of the environment.

The following ORD components contributed to the research described above:

- Office of Energy, Minerals & Industry—Industrial Environmental Research Laboratory, Research Triangle Park

oil shale

ORD develops pollution control guidance for an emerging industry

Oil Shale is a layered, brown sedimentary rock found primarily in Utah, Colorado, and Wyoming, and contains more potential energy than U.S. oil and natural gas reserves combined. To get the oil out of the shale, however, these rocks must be heated in aboveground facilities or in specially prepared underground caverns. Both above ground and in situ techniques for shale oil extraction involve mining, crushing and combustion—all processes that can generate a host of environmental problems.

Today, with the need for greater energy self-sufficiency and the high price of fuels, industry interest in oil shale development is at an all-time high. A number of developers are currently planning to achieve commercial production of shale oil within the next few years, and as many as a dozen such facilities could be put in operation during the 1980's.

The emergence of such an industry—one capable of providing enormous amounts of energy, yet also capable of causing significant environmental damage—deserves the closest scrutiny by regulatory agencies. It is just as important, however, that the developers, who bring millions of research, development, and construction dollars to the task, know what will be expected of them in the way of environmental regulations and control technologies. This is necessary to avoid costly retooling after start-up and time-consuming challenges in the courtroom.

To meet the needs of this emerging industry, ORD oil shale research efforts in recent years have been directed toward anticipating EPA regulations and standards and the development of control technologies to meet these potential regulations and standards. In total, ORD laboratory research has involved: techniques of measuring and monitoring air and water quality, instrumentation methods, quality assurance programs, the fate of pollutants, the effects of pollutants on humans, the effects of pollutants on ecosystems, the environmental assessment of regions of potential oil shale development, as well as the development of control technologies for oil shale extraction and processing.

Because of the number of ORD offices involved in this effort, EPA researchers formed an Oil Shale Working Group that meets periodically to increase cooperation on research projects and to improve interlaboratory communications.

Oil Shale Pollution Control Guidance Document

The culmination of this extensive ORD research effort came in 1978 with the drafting of a comprehensive report entitled "Pollution Control Guidance for Oil Shale Development." This document, intended for use by developers as well as regulators of this emerging industry, presents pollution control guidance that anticipates, and to some extent serves to set the stage for, the EPA regulatory posture on oil shale development. Coming on the heels of a similar document for geothermal energy development, this publication is only the second such effort that attempts to delineate so clearly the environmental parameters of an industry not yet fully in existence.

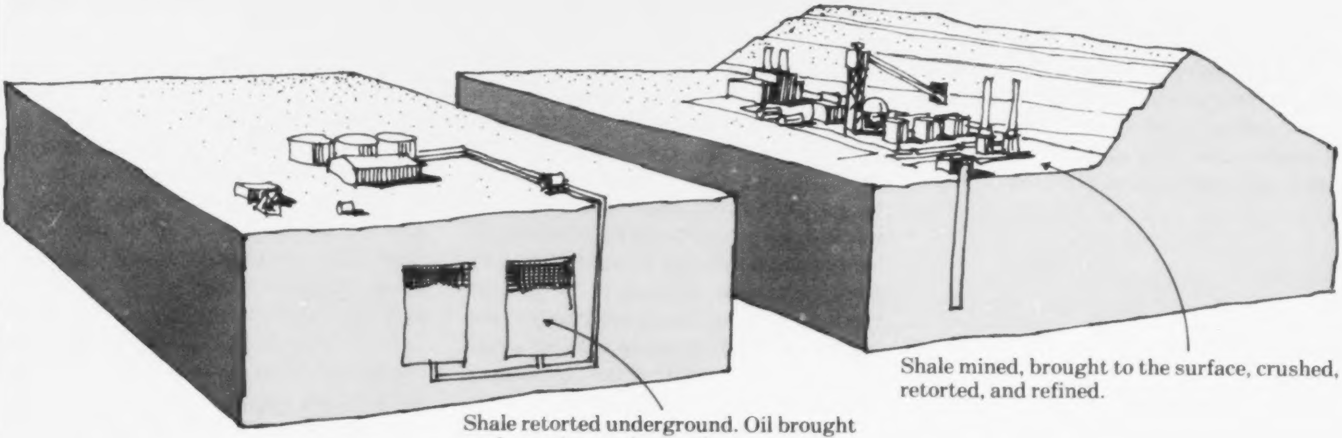
Specifically, the document presents numerical estimates of EPA regulatory standards and required control measures that may be expected for the oil shale industry, as well as estimates of discharge and emissions limitations. These estimates are based on a thorough analysis of existing technical data in conjunction with anticipated regulatory mechanisms. The document is divided into five major sections to include an extensive introduction, recommendations for air emissions, water effluent and solid waste disposal regulations, a detailing of environmental impacts expected as a result of oil shale development processes, specific control technology data, and methods for monitoring emissions, effluents, and solid wastes.

To assure the utility of this document, input, participation, review, and concurrence was sought throughout the EPA program offices. In this manner, the regulatory mechanisms and discharge limitation goals set forth in the document reflect the thinking of the agency as a whole, rather than that of a single office. The coordination of this effort is being carried out through the Energy Technology Committee made up of ORD and program office representatives.

After the guidance document has been reviewed and approved by EPA, it will be circulated to other governmental agencies and to industrial groups for further review and comment. Final publication is scheduled for December 1979.

The following ORD components contributed to the research described above:

- Office of Energy, Minerals & Industry—Industrial Environmental Research Laboratory, Research Triangle Park; Industrial Environmental Research Laboratory, Cincinnati; Office of Health & Ecological Effects—Environmental Research Laboratory, Duluth; Health Effects Research Laboratory, Research Triangle Park; Office of Monitoring and Technical Support, Environmental Monitoring and Support Laboratory, Las Vegas; Office of Air, Land & Water Use—Robert S. Kerr Environmental Research Laboratory, Ada; Environmental Research Laboratory, Athens


Shale retorted underground. Oil brought to the surface and refined.

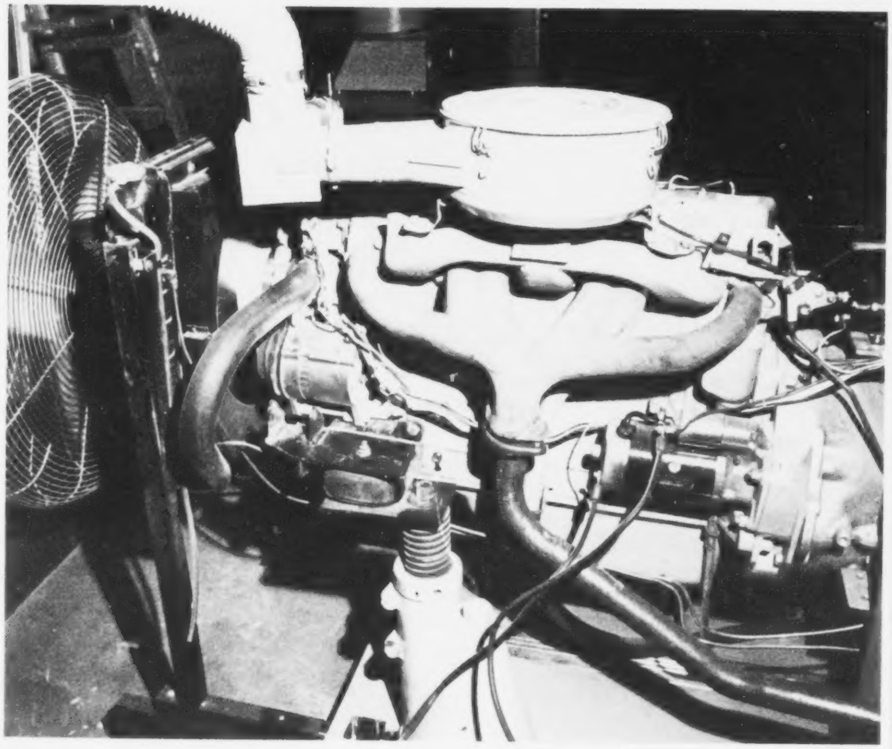
Shale mined, brought to the surface, crushed, retorted, and refined.

"IN SITU"

ABOVE GROUND

diesels

ORD is studying potential public health threats of diesel exhaust



The diesel powered passenger automobile is capable of approximately 25% better fuel economy than its spark ignition gasoline powered counterpart. Diesel engines also are able to meet virtually all of the 1980 EPA emissions standards for carbon monoxide, nitrogen oxides, and hydrocarbons with a minimum of technological modifications. By 1985, the industry estimates that 25% of new U.S. automobiles sold will be diesel powered.

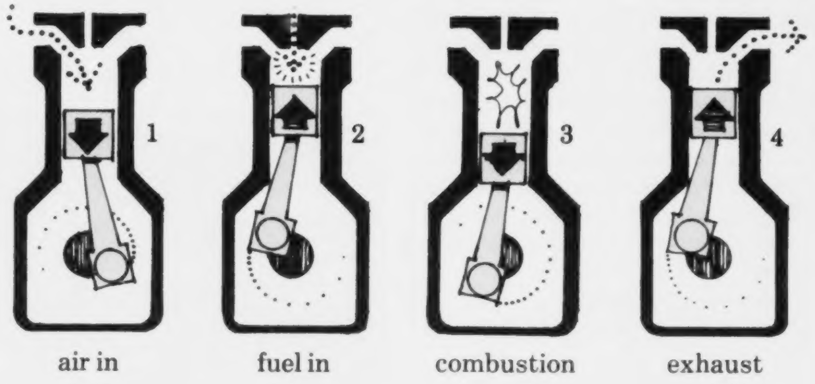
In view of the projected increase in diesels on American roadways, EPA embarked on a program in 1971 to evaluate the potential public health problems posed by diesel automobile exhaust products. Already known was that a single diesel powered automobile emitted 30 to 50 times more particulates than a comparable gasoline powered vehicle equipped with a catalytic converter, and that the composition of these particulates differed.

Particulates emitted from a gasoline powered vehicle are principally sulfuric compounds and low molecular weight organic substances. Emissions from a diesel powered vehicle, however, contain primarily carbon particles with higher molecular weight organics such as polycyclic aromatics that attach themselves to the particles' surface; some of these aromatics give the diesel exhaust its characteristic smell. The actual percentage of these organics per particle depends on engine and fuel type and driving cycle, and varies from 10% to 50% with about 25% considered to be a reasonable average. Most of the particles are less than one micron in size and are therefore respirable. That is, they are small enough to slip through the lung's protective mechanisms and lodge deeply in lung tissue where they can cause various biological changes.

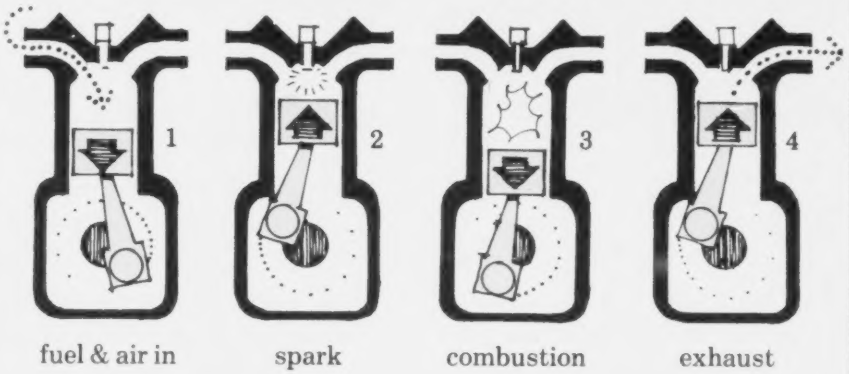
EPA Research Results

Late in 1977, EPA released preliminary results of tests performed on diesel exhaust organics emitted by medium and heavy duty engines at ORD's laboratory in Research Triangle Park, N.C. Samples of the organic extracts from these particulates were introduced into an Ames microbial mutagenicity bioassay test system, an *in vitro* (outside the living body) system that measures mutagenicity of chemicals on colonies of bacteria. Results of this research, although inconclusive, indicated that the organic materials tested were consistently mutagenic for this test system. Many investigators believe that the organics found in diesel exhaust might also be carcinogenic.

It is important to note, however, that almost all combustion products generally *do* contain carcinogens, and that the results of *in vitro* screening systems such as the Ames test are not conclusive, but merely aid researchers in finding suspicious compounds to concentrate on in animal and other types of biological studies.



In a conventional four-cycle engine, shown below, a compressed mix of gas and air is ignited by a spark plug. In a diesel engine, shown above, a heavy fuel oil is ignited when injected into very hot, highly compressed air.



WHAT IS THE DIESEL DIFFERENCE?

1978 Highlights

In 1978, more recent research findings were presented at a symposium of scientists looking into means to measure biological effects of diesel exhausts. Here, Ames system results and methods were discussed along with additional diesel sample activity findings. Other *in vitro* tests were presented. The results of these tests showed that some diesel particulates produce DNA damage in yeast and mutation of mammalian gene-cells. It is not possible, however, to draw any harmful health effect conclusions from 1978 diesel emissions data.

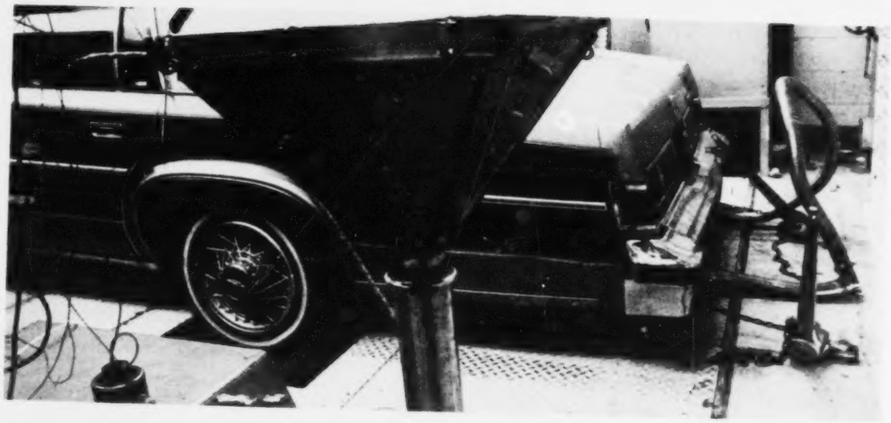
Additional important research isolated specific compound groups in which the mutating agents were particularly potent. This will enable further research to concentrate investigations on the offensive compounds. Further findings show that mutagens were not created as a result of laboratory extraction, fractionalization or storage, nor are they present in uncombusted diesel fuel. Mutagenicity thus appears to be a direct consequence of combustion.

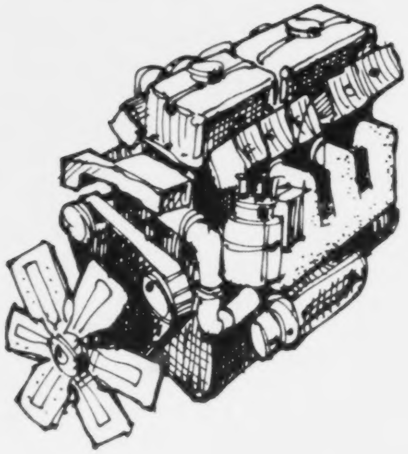
50-Day Pilot Study

A 50-day pilot study exposing cats, rats, mice and guinea pigs to diluted raw exhaust from a light duty six-cylinder diesel engine was completed at ORD's Cincinnati laboratory. The study was designed to identify the acute effects that might result from short-term, high-level exposure to diesel exhaust. Unlike the *in vitro* screening studies, in which only the particulate components of the diesel exhaust were introduced into the research, whole animals were exposed in this study to both the gaseous and particulate portions—the total exhaust—simultaneously. Such an examination is important in investigating the effect of diesel emissions since approximately 80% of the pollutants emitted from light duty diesels remain in the gaseous phase.

The following biological effects were measured:

- pulmonary functions
- increased susceptibility to respiratory infection
- deposition and clearance of particulates entering the lungs
- lung and other pathology
- biochemical changes in the lung and other tissues
- pulmonary tumor development
- lung changes for indications of fibrosis and emphysema
- changes in behavioral activity.





Initial study results indicate:

- little or no change in pulmonary function
- an increased susceptibility to respiratory infection (perhaps due to elevated levels of NO_2 present in the partly diluted exhaust)
- particulates enter the deep regions of the lungs; a slow rate of clearance permits long residence times
- no significant pathological changes occur either in the lung or other body tissues (possibly due to shortness of exposure)
- increased levels of arylhydrocarbon hydroxylase (AHH) in the lungs, testes, and prostates; may be correlated with the chemical induction of tumors
- increased levels of total protein in the lungs, suggesting longer exposure might result in fibrosis and emphysema-like lung destruction
- no pulmonary or other organ tumors
- significant changes in spontaneous locomotor and forced activity (may be related to sensory perceptions of the exposure conditions).

These results will be compared with similar studies that have been conducted with gasoline catalyst and noncatalyst engines. It is important to note, however, that this test was only a study of acute health effects, using one engine, one fuel, and one driving cycle. And while these results fail to confirm any significant acute effects, any future deleterious findings will be coupled with *in vitro* results to identify areas of potential concern. As with the *in vitro* testing, the scarcity of data precludes conclusions about diesel emissions and public health risks.

Future Research

The primary direction of future research into diesel emissions will focus on their specific carcinogenicity. While noncarcinogenic diseases such as fibrosis and emphysema may also be induced by diesel emissions, it is felt, nevertheless, that such effects are not unique to diesel particulates, and therefore do not require study in this context. However, a special diesel exhaust inhalation study is now underway to test the validity of this assumption.

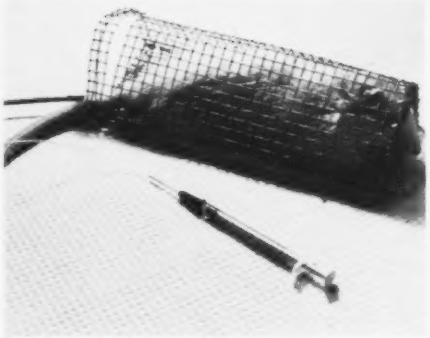
The future carcinogenic studies will be carried out using three major techniques: *in vitro* screening, whole animal tests, and epidemiology.

In Vitro Screening

In vitro screening will involve the continued evaluation of the particulate and gaseous components of diesel exhaust using different fuels, engines, and driving cycles. With this information, an attempt will be made to determine those alterations that can be made in engines, fuels and emission controls to eliminate positive mutagenic responses as determined by the Ames system.

Additionally, the relative biological potency of the particulates will be compared with their actual quantity in the diesel exhaust. ORD will then be able to rank order those substances that require future *in vitro* studies and those to be introduced into higher order biological tests.

To determine the comparative potency of diesel particulates, samples will be obtained from other sources such as gasoline powered automobiles, coke ovens, cigarette and roofing tar and ambient air, and will then be subjected to similar *in vitro* tests. Yet another *in vitro* study will determine whether diesel particulates are mutagenic under physiological conditions similar to those found in the lung.



Whole Animal Studies

Two sets of animal studies will be performed in further research. The first set of experiments will introduce higher priority particulate samples (determined by *in vitro* testing) or individual compounds into animals, either by instillation (drop-by-drop application), skin painting, implantation, or injection. The animals will then be examined for increased evidence of tumors. Parallel studies will be performed with coke oven particulate emissions and cigarette and roofing tar for which a data base between dose response and human cancer exists.

The second set of whole animal studies will involve exposing several species of animals via inhalation to total diesel exhaust. Here, both carcinogenicity and a limited examination of noncarcinogenic chronic lung disease will be studied. Groups of normal mice and rats will breathe the diesel exhaust over their lifetimes. Although it is not expected that tumors will be discovered owing to the low concentration of organics in the exhaust, the animals will be closely examined for any unexpected results.

In some of the inhalation studies, strains of animals particularly susceptible to tumor growth will be used to determine whether tumors develop faster or more readily in animals exposed to a diesel atmosphere than in control animals. Other animals will be exposed to a known animal carcinogen at a dose sufficiently low that it should *not* produce tumors, and then will be exposed to the diesel exhaust for the remainder of their lives. This will be done to further determine whether diesel exhaust makes the development of tumors more likely. Additionally, animals will also be studied for evidence of emphysema-like destruction of their lungs.

Epidemiological Studies

ORD will identify the geographic locations where epidemiological research will be useful in the study of diesel exhaust emissions. Studies will be initiated and expanded as warranted; however, owing to the long lead times necessary for such study, heavy reliance on existing NIOSH (National Institute for Occupational Safety and Health) and other epidemiological research will be required.

Conclusion

It is currently not possible to define the potential public health effects of the expanded use of diesel engines in automobiles. No one study is sufficiently definitive, and too few studies have been completed. It is assumed, however, that by November 1979, when EPA obtains the results from its current research, that a sufficient health effects data base will exist from which to establish a reasonable set of recommendations concerning this significant change in American automobile power generation. That research will be reported in "Research Highlights—1979."

The following ORD components contributed to the research described above:

- Office of Health & Ecological Effects—Health Effects Research Laboratory, Research Triangle Park

monitoring air quality

Emissions are measured in energy development areas and from natural sources

There is little doubt that the accelerated use of our energy resources will significantly impact air quality in those areas where this activity will center. Today, EPA is supporting a comprehensive program to evaluate the real and potential air quality impacts of these developments in the western United States. Of particular interest are proposed developments in the eight state region encompassing the Northern Great Plains, the oil shale regions of Colorado and Utah, and the Four Corners area where Utah, New Mexico, Arizona, and Colorado meet.

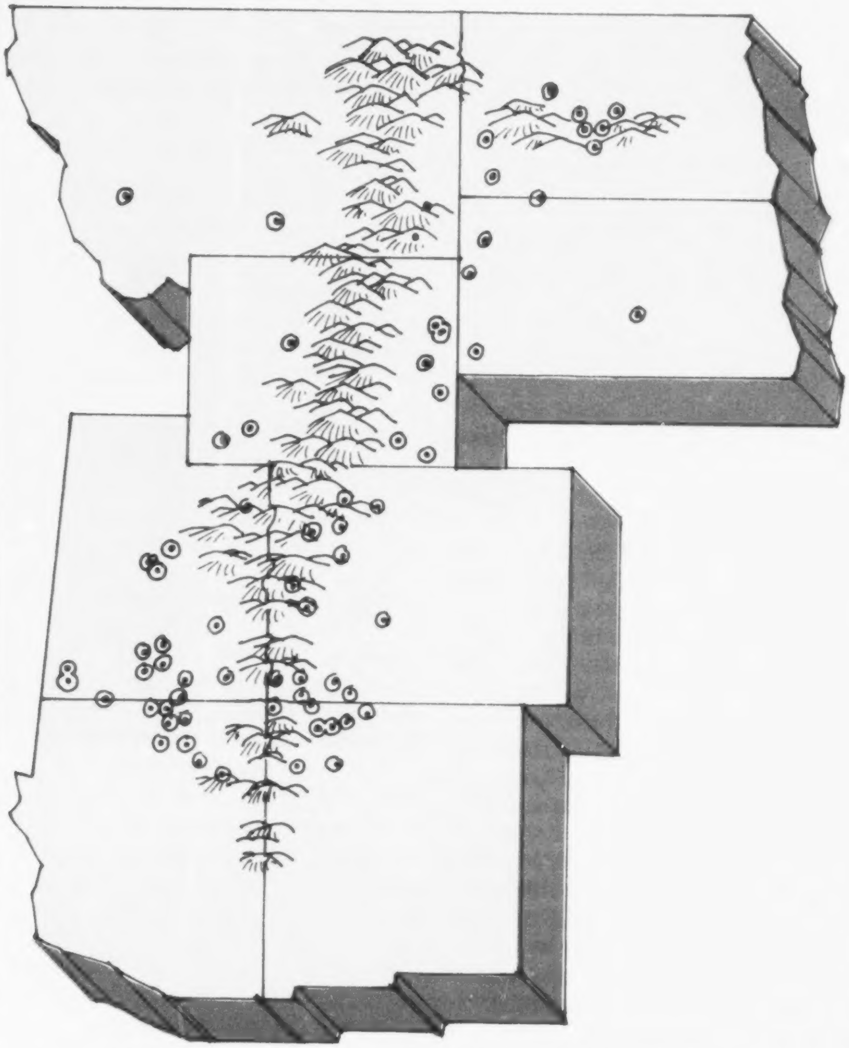
The primary objectives of this program are to establish an energy-related air quality baseline and subsequently to evaluate air quality trends. In this manner, a quantitative measure of the regional air quality impacts of existing and currently planned developments can be established so the air quality impacts of any proposed and future energy-related activities can be predicted.

Meeting the Objectives

To meet the objectives of this comprehensive study, it was essential first to inventory existing air quality monitoring stations in the eight state Western Energy Resource Development Area (WERDA) and the sources of potential energy-related air pollution. The next step was to determine if a sufficient number of stations existed and whether or not they were properly located for the study. Additionally, existing operations were examined to determine the adequacy of the stations in light of the anticipated monitoring requirements.

It was discovered that the density of air quality monitoring stations was particularly low in most of the areas with anticipated large-scale energy activities. It was also found that existing stations were not specifically designed to characterize impacts of energy developments, nor were their measurements completely focused on air pollution stemming from power plant emissions, which are considered to represent the greatest near-term, energy-related impact on air quality. While the presence of sulfates and fine particulates, which result in degraded visibility, are the most obvious manifestation of such developments, sulfates were being monitored at only few locations, and neither fine particulates nor visibility degradation were being monitored on a regular basis at any location.

Part of the preliminary work also involved a complete cataloging of existing and proposed electric power generating facilities, proposed oil shale development sites, and proposed coal conversion facilities, along with schedules for their implementation. With electric power generation in the WERDA region expected to triple between 1975 and 1985, it was obvious that coal-fired power plant development represented the most immediate and extensive potential impact on the region; therefore, a 10-year scenario outlining the problems of maintaining good air quality from present and proposed electric generating facilities was prepared.

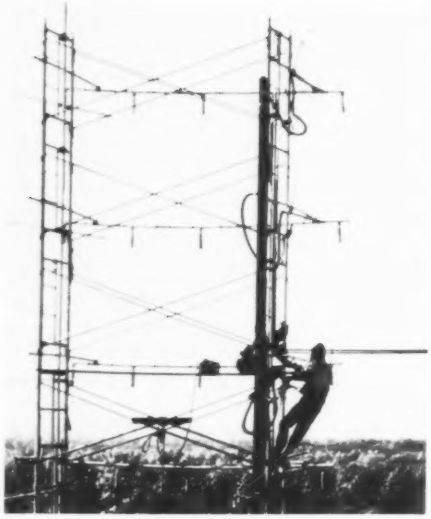


NEW SULFATE-NITRATE MONITORING SITES

Natural Air Pollution

To establish an air quality baseline for developed areas, it is often necessary to determine the type and concentration of pollutants that exist naturally in the atmosphere. Natural hydrocarbons, for example, are liberated from many types of vegetation. It is estimated, in fact, that ten billion tons of such hydrocarbons are emitted world-wide into the atmosphere each year. While no apparent health problems are posed, the hydrocarbons do produce aerosols that reduce visibility in certain mountain areas.

In recent years, however, high ozone levels often exceeding the air quality standard of 0.08 ppm have been measured in many rural areas far from any significant human-made emissions sources. While ozone and ozone-producing substances can be transported great distances, it is also possible that this ozone is a result of the photooxidation of naturally emitted hydrocarbons.



Pine forest undergoing testing for hydrocarbon emissions

Baseline Monitoring in the West

Most recent highlights in this ORD baseline study include the initiation of an aircraft monitoring program to determine the regional distribution and dynamics of pollution, the operation of a Four Corners particulate characterization monitoring network, the development of a visibility monitoring capability, and the use of regional scale air quality simulation modeling.

As part of an expanded sulfate monitoring network, Montana, North Dakota, South Dakota, and Colorado are now performing sulfate analysis on particulate samples collected at 32 stations. This is being funded in part through ORD's Las Vegas laboratory and through EPA's Region VIII grant programs to these states. The Ute Research Laboratories, under contract to the Las Vegas laboratory, is performing sulfate and nitrate analysis in the Four Corners network (28 stations) and will expand the program in 1979 to include samples collected from 16 sites in Utah and Wyoming. In total, these 76 additional stations, together with those sites already performing sulfate analysis, will comprise the ORD western energy sulfate monitoring network.

Additionally, the Las Vegas laboratory is engaged in a program of field testing several particulate samplers to determine those instruments that can be most effectively used in a fine particulate monitoring capacity.

With the data being taken by these monitoring activities EPA will have a quantitative baseline in WERDA for measuring air quality impacts of energy-related activities. From this reference mark it will then be possible to trace pollution trends from planned major expansions of coal combustion and conversion and oil shale development. Such information will be invaluable in making future policy decisions concerning air quality protection and energy development in this region.

Hydrocarbons from Pines

ORD's environmental sciences laboratory has been investigating the role of natural hydrocarbons in the production of ozone. Two recent complementary studies were performed. The first measured the emissions levels of loblolly pines, the second examined the photochemical reactivity of natural hydrocarbons.

The Emission Study

Previous estimates of vegetative emissions were based on values obtained from a single branch of sapling in an enclosure. These figures were then extrapolated to the whole mature plant. Inherent in this technique were two problems. First, the enclosure itself often had an effect on the emission rate in that enclosing a plant could raise its temperature or damage it, thus causing higher than normal emissions. Second, even if the greatest care were taken in simulating natural conditions in the enclosure, the enclosed branch or sapling was not necessarily representative of the total vegetative surface.

To circumvent these shortcomings, ORD developed a technique in 1978 to measure the emissions from a loblolly pine forest in North Carolina. The energy balance of the forest's entire tree canopy was calculated by using measurements of net radiation, water vapor, temperature, carbon dioxide, wind speed, and vertical gradient of alpha-pinene, a hydrocarbon produced by conifers. From this information it was possible to calculate the net loss of incident radiation by various energy absorbing processes, and ultimately to provide ORD researchers with a measure of the alpha-pinene emissions. It was found that the higher the temperature, the greater the amount of alpha-pinene produced.

Owing primarily to the effectiveness of the energy-balance equation technique, it was possible to conclude that the range of alpha-pinene production values were indeed an accurate measure of total alpha-pinene emissions from the forest, from all living and dead vegetative surfaces including foliage, bark, and litter.

A simple diffusion model calculation was then made to test whether the alpha-pinene produced could impact a city's air quality. Based on an alpha-pinene production rate much higher than was observed in the measurement study a conifer forest 100 km in depth should produce certain levels of natural hydrocarbon within a city 1 km downwind. Field studies performed in a number of U.S. cities, however, show no such concentrations of alpha-pinene.

Additionally, when measuring the potential effects of these hydrocarbons, it is important to note that the compound inevitably diminishes as it reacts with existing urban photochemical products and ozone. Past photochemical modeling studies show that the resulting hydrocarbon level is not sufficient evidence to blame a large pine forest upwind of a city for that city's poor air quality.

Emissions from hardwood vegetation were not measured in this study. However, past EPA field studies show that the daytime isoprene—the principal hydrocarbon emitted from hardwoods—concentration is not significantly different from the daytime alpha-pinene concentration found in conifer forests. And, during nighttime, any isoprene concentration is expected to be much lower since the level of emission depends on the amount of solar radiation.

Photochemical Reactivity Measurement

Since even low concentrations of hydrocarbons could, if they were extremely efficient, produce high levels of ozone (and actually be partially responsible for the poor air quality of a city downwind), it was necessary to examine the photochemical reactivity of these compounds. Eight natural hydrocarbons were chosen for this 1978 ORD study, with propylene used as a reference compound because a great deal of empirical data existed on that substance.

The results of this study showed that propylene gave rise to the most ozone when it reacted with oxides of nitrogen. Isoprene was second, and the remaining seven natural hydrocarbons all produced approximately 65% of the ozone produced by the propylene. But since propylene is only moderately efficient in producing ozone, on the basis of this study it was concluded that the eight natural hydrocarbons were not efficient ozone producers.

In Conclusion

Results of these studies tend to support the conclusion that natural hydrocarbons do not significantly affect the air quality in urban areas since their concentration is low and they are not efficient in producing ozone.

The following ORD components contributed to the research described above:

- Office of Air, Land & Water Use—Environmental Sciences Research Laboratory, Research Triangle Park

air pollution index

ORD develops a national index and measures air pollution costs

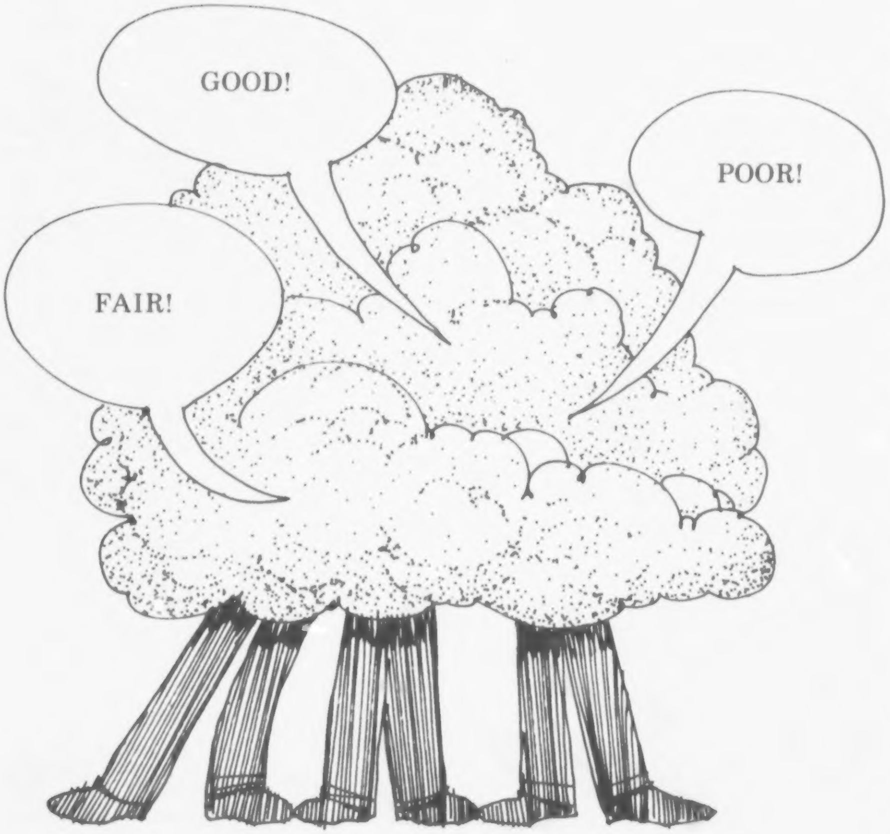
In August 1977, Congress passed the Clean Air Act Amendments. This legislaion, in part, mandated that a single, uniform national air quality index be estabished. Having anticipated the need for an ndex a number of years earlier, EPA had by 1977 developed the Pollutant Standards Index (PSI), a tool already in extensive use at the time of the Amendment's passage.

The Pollutant Standards Index

PSI was derived from the widely-used National Ambient Air Quality Standards (NAAQS) episode, criteria and health-related significant harm levels. The index currently contains all pollutants or combinations of pollutants for which national standards exist, and is designed to accommodate any additional pollutants as they come under regulation.

Basically, PSI works like this: Each pollutant is assigned a numerical value based on its concentration in the atmosphere. A PSI value of 100 is equal to the NAAQS, and a PSI value of 500 corresponds to the significant harm level of a given pollutant. Thus, a PSI value of over 100 indicates a violation of a standard, while one approaching a PSI of 500 indicates far more severe danger. On any given day, the value of *all* the pollutants measured that day are assigned a value on this scale, and the *highest single value* becomes the PSI for that day.

PSI was also designed with simplicity of communication to the general public in mind. Either short or detailed reports could be used. For example, on a "good" day, a report might be, "Today the air pollution index is 40; the air quality is good." On days when air pollution yields a PSI of over 100, the report could take on the following, successively more detailed forms: "Today the air pollution index is 150; the air is unhealthful. The pollutant responsible is ozone." And, additionally, "Persons with existing heart or respiratory ailments should reduce physical exertion and outdoor activity;" and/or "This air quality can cause mild aggravation of symptoms in the healthy population." Finally, a PSI forecast: "We expect that the air quality will improve (stay the same, worsen) tomorrow."


GOOD!
FAIR!
POOR!

Genesis of PSI

The development of PSI began in May 1974, when ORD initiated a national survey of air pollution indices used by air pollution control agencies and those appearing in the scientific literature. The study was jointly supported by EPA and the Council on Environmental Quality (CEQ). Survey findings indicated that of the 33 cities using daily air pollution indices, no two were exactly the same. Consequently, a traveler leaving a Cincinnati index of "25" and arriving to a New York index of "25" might find that, in fact, the air he was breathing had changed from "excellent" to "unhealthy." The study also revealed that cities were highly inconsistent in the terms they used to define air quality. A given pollution concentration might thus be defined as "moderate," "fair," "normal," "good," or "satisfactory." The upshot of this lack of standardized reporting was that the public need for air quality information was not being met, particularly for the elderly or infirm among the population, who were the most in need of reliable and consistent data.

This same CEQ-ORD study also developed a system of classifying air pollution indices and identified ten essential criteria a nationally uniform air pollution index should meet. Two such index structures were recommended and a joint CEQ-EPA task force was established to make the selection. A second group within EPA was formed to prepare technical guidelines that would assist state and local agencies in implementing the new index, once it was decided which one to adopt. This group also developed a special computer program which enabled the index to be tested on actual data, as well as standardizing language that would describe the health effects of the different ranges of the index.

Ultimately, PSI was the outgrowth of these efforts. In September 1976, it was published in the *Federal Register* as a recommended air pollution index, and by 1977 it had been evaluated and proposed by many air pollution control agencies.

1978 Research Highlights

In 1978, EPA chose PSI as the nationa index, owing in part to its desirable characteristics and also to its acceptance by loca and state air pollution control agencies. I

August, PSI was again published in the *Federal Register,* this time in the form of regulations adopted pursuant to Section 319 of the Clean Air Act, as amended.

With PSI now becoming mandatory, it was felt that state and local air pollution control agencies would require effective techniques to calculate PSI values accurately and rapidly. To provide these techniques ORD prepared a number of reports containing tables, charts, and computer programs and made them available to agencies throughout the country.

In the Spring of 1978, the Office of Air Quality Planning and Standards (OAQPS) gathered information from the ten EPA Regional Offices on the progress of nationwide PSI adoption. It was found that 14 state agencies had formally adopted the index, and that the index was being used in 24 states and approximately 100 urbanized areas. Full adoption by all states is expected.

OAQPS continues to monitor the adoption of PSI and assists state officials in solving problems they might encounter in its use. While EPA has not yet selected a uniform procedure to report national trends or to compare different urban areas, OAQPS is currently looking at a variety of graphical techniques that might be used to incorporate PSI figures in its annual trend reports.

STATE	**URBAN AREAS USING PSI**
Connecticut	Bridgeport[a], Derby, Enfield, Greenwich, Groton, Hartford[a], Middletown, New Britain, New Haven[a], Waterbury
Massachusetts	Boston[b], Springfield[b,c]
New York	All Major Urban Areas: Albany, Birmingham, Buffalo, Elmira, New York City, Rochester, Syracuse, Utica, Troy
Maryland	Baltimore
Pennsylvania	Allentown[a], Baden, Beaver Falls, Bethlehem, Bristol, Charleroi, Chester, Harrisburg[a], Johnstown, Lancaster, New Castle, Morristown, Reading, Pittsburgh[b], Scranton[a], Wilkes-Barre[a], York
Virginia	Norfolk, Richmond[a]
West Virginia	Charleston, Wheeling
Alabama	Birmingham[a], Huntsville, Mobile[a]
Florida	Jacksonville[b], Miami[b], Palm Beach, Sarasota, Tampa-St. Petersburg[b]
Georgia	Atlanta
Kentucky	Ashland, Henderson, Lexington, Louisville
Tennessee	Chattanooga[a], Memphis[a], Nashville
Indiana	Indianapolis[b]
Michigan	Detroit[b]
Ohio	All Major Cities in Ohio Including, Akron, Ashtabula, Canton[a], Cincinnati, Cleveland, Columbus[b], Dayton, Mansfield, Portsmouth
Wisconsin	Milwaukee[b], Racine
Texas	Fort Worth[b]
Iowa	Cedar Rapids, Des Moines[a]
Kansas	Wichita[a]
Colorado	Denver[b]
California	Southern California Air Pollution Control District—Reports forecasted air quality for four zones daily. Some urban areas covered include: Anaheim, Azusa, Burbank, Los Angeles[b], Pasadena, Riverside and San Bernardino. Fresno[a], San Francisco, San Diego, Sacramento
Oregon	Corvallis, Eugene, Medford, Portland[b], Salem
Washington	Seattle[b], Tacoma[a]

a) Urbanized areas greater than 200,000 but less than 500,000 population (1970 Census).
b) Urbanized areas greater than 500,000 population (1970 Census).
c) Underlined places means that the PSI will be implemented in the near future.

Economic Benefits of Air Pollution Control

Information from a major new study suggests that the health benefits of controlling air pollution from stationary sources are more than double the costs of control.

The new study, prepared for ORD by three western universities, concludes that the health benefits from air pollution control are much larger than previously estimated. Computations using estimates of the cost of control from the federal Council on Environmental Quality and data from EPA's air monitoring, show that the current benefits of stationary source control exceed the costs by a factor of at least 2.

The calculation is based on an EPA-calculated 12 percent reduction in particulate air pollution as of 1977, compared to particulate levels before the Clean Air Act was passed in 1970. The study data imply that health benefits of more than $8 billion per year would correspond to that pollution reduction. Since total annual costs attributable to federal pollution control regulations for stationary source air pollution control were estimated by CEQ to be $4 billion in 1976, the benefit-cost ratio is thus at least 2 to 1.

For higher levels of control, the study estimates commensurately greater benefits. At 60 percent control, for example , the value of improved health in urban areas would be at least $5 billion per year for reduced deaths and $36 billion for reduced illness—a total of about $41 billion per year. That amount is equivalent to about $190 per year per person.

Results are Conservative

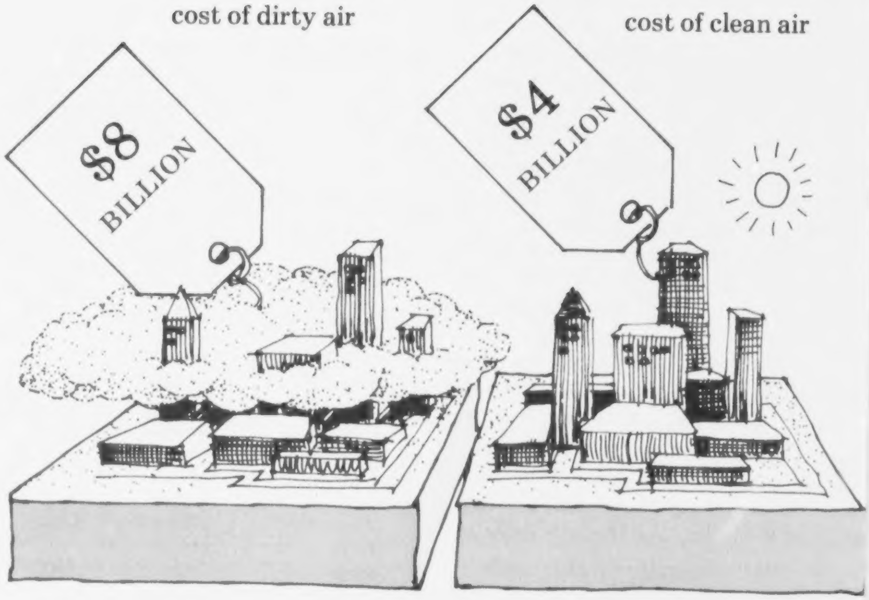
The benefit-cost ratio may too low since the costs have been purposely overestimated and the benefits of control underestimated. The reduction in particulate levels is underestimated as well, since the levels would almost certainly have increased without the Clean Air Act.

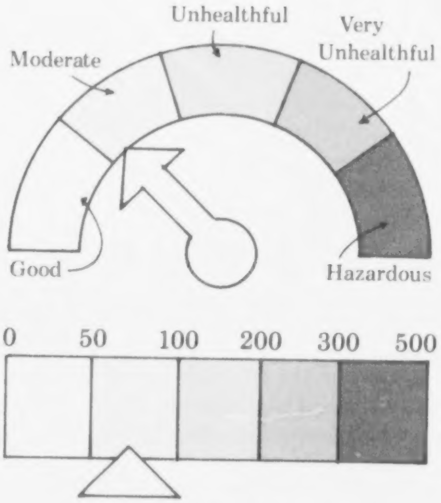
The costs are overestimated because all expenditures for control of stationary sources were included, even though those expenditures also control pollutants other than particulates and sulfur dioxide, the only pollutants included in the estimate of benefits. Costs for controlling mobile sources (primarily automobiles) were excluded, however, since mobile sources do not contribute substantially to levels of particulates or sulfur dioxide.

Similarly, the benefits are underestimated: The study did not include any nonhealth benefits such as decreased soiling of exposed articles, reduced plant damage or improved visibility; the estimates of health damage ignore the benefits of reduced air pollution-related illnesses other than those concerned with lost workdays; and the $5 billion death estimate is based on an estimate of the economic value of decreased risk.

New Perspective on Damages

Besides suggesting that previous studies may have substantially underestimated both the health and other economic damages from air pollution, and thus the benefits of control, the new study and other recent work suggest a new perspective on air pollution damages and their measurement.





EXAMPLES OF T.V. PSI REPORTS

The new work indicates that the major air pollution damages are from increased chronic illness and from aesthetic effects such as reduced visibility. This contrasts with earlier views that increased deaths were the major source of damage.

The economic damages attributable to increased air pollution-related deaths are roughly comparable to earlier studies, but this is largely accidental: although the new estimates of mortality effects are lower than earlier studies have indicated, these lower estimates are offset by higher estimates of the value society places on increased risk of death.

Derivation of New Health Estimates

The researchers derived their estimates of damage to health through two independent approaches. One approach examined data on illnesses among a random selection of the U.S. population. This information was compared statistically with indicators of biological and social situation, life styles, income levels, physical environment, and air pollution levels in the county of residence. The analyses suggest the extent to which each indicator is associated with time lost from work because of illness.

The studies found statistically significant associations between lost work time because of chronic illness and ambient levels of both nitrogen dioxide and total suspended particulates. The researchers arrived at the $36 billion estimate by projecting the relationship between lost time and particulate levels in the sample to the national urban population, using the wage rates of the sample population to put a monetary value on the time lost from work. The authors emphasized, however, that their conclusions should be regarded as preliminary because of the short time they have worked with the data and the many combinations of explanatory hypotheses they will need to test.

In the second approach, the researchers concentrated on death rates in 60 cities across the country, comparing the rates to air pollution levels and other factors that might influence death such as smoking, doctors per capita, and diet. They found statistically significant associations between deaths from pneumonia and influenza and the level of particulates in the air, and between early infant disease and the level of sulfur dioxide.

Los Angeles Benefits Also Large

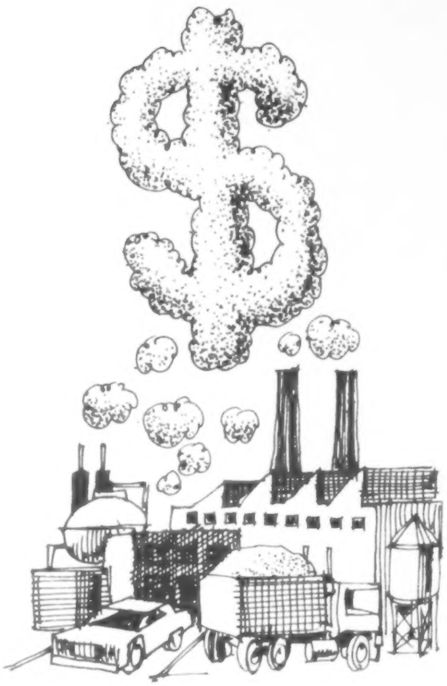
In addition to studying health damages from air pollution, the same study also attempts to quantify air pollution damages in one air quality region—the Los Angeles Basin. It found that a 30 percent improvement in air quality would provide benefits of $650 to $950 million per year (or $350 to $500 per household) for this city alone.

This part of the study used interview surveys and analyses of property values to support its conclusions. In the interview survey, people were first given a subjective understanding of the health effects and location of Los Angeles smog using maps of pollution levels (which varied from poor to quite good) throughout the Basin and later were shown photographs of a view obscured by different levels of pollution. They were then asked how much they would be willing to pay for improved air quality. In the property value analyses, the researchers compared the selling prices of houses which were similar but which were located in areas experiencing different levels of pollution. The houses in the clean air areas had a substantially higher value than those in more polluted areas. The fact that the benefit estimates derived from the two approaches are similar lends credence to both.

In their interview survey, the researchers found that people living in the Los Angeles Basin believe aesthetic effects such as impairment of visibility account for from 22 to 55 percent of the damages associated with air pollution. These findings are consistent with an earlier survey which found that people living in the Four Corners area of the Southwest would pay an average of $90 a year to avoid having visibility reduced by 50 miles, from 75 to 25 miles.

Looking Ahead

The benefits study is part of an overall program of economic research. The program, in existence since 1971, has recently emphasized the development of improved means for estimating the benefits of EPA programs and the relative benefits and costs of individual regulations. Further research wil be carried out during 1979 on both the benefits of air pollution control in Los Angeles and from reduced illness nationally; a report on this added research is due in October.



Although some of the results of the new study related to damages from illness are still preliminary, and will be further refined in the October report, they provide an important new insight into the benefits an air pollution control program can achieve and into how these benefits can be estimated. It concludes that many benefits, such as aesthetic ones, which are traditionally viewed as intangible and thereby non-measureable can, in fact, be measured and can be made comparable to economic values expressed in the marketplace.

The following ORD components contributed to the research described above:

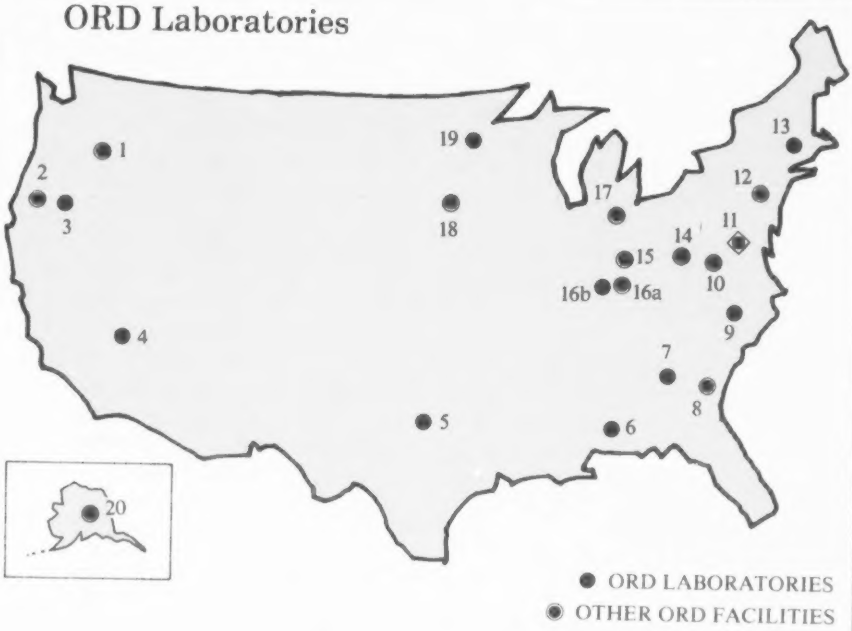
- Office of Monitoring and Technical Support—Headquarters

ORD resources

Fiscal 1978

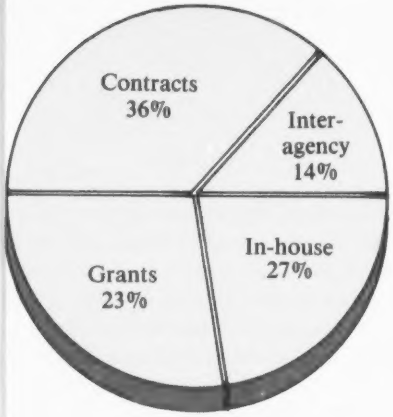
$295.6 Million
1365 Positions

ORD Laboratories



1 Wenatchee, Washington (OHEE)
2 Newport, Oregon (OHEE)
3 Corvallis, Oregon
Environmental Research Lab. (OHEE)
4 Las Vegas, Nevada
Environmental Monitoring and
Support Lab. (OMTS)
5 Ada, Oklahoma
Robert S. Kerr Environmental
Research Lab. (OALWU)
6 Gulf Breeze, Florida
Environmental Research Lab. (OHEE)
7 Athens, Georgia
Environmental Research Lab. (OALWU)
8 Bears Bluff, South Carolina (OHEE)
9 Research Triangle Park, N.C.
Environmental Monitoring and
Support Lab. (OMTS)
Industrial Environmental Research Lab.
(OEMI)
Environmental Sciences Research Lab.
(OALWU)
Health Effects Research Lab. (OHEE)
10 Warrenton, Virginia (OMTS)
11 Washington, D.C.
Headquarters, OR&D
12 Edison, New Jersey (OEMI)
13 Narragansett, Rhode Island
Environmental Research Lab. (OHEE)
14 Rivesville, West Virginia (OEMI)
15 Lebanon, Ohio (OALWU)
16a Newtown, Ohio (OHEE)
16b Cincinnati, Ohio
Environmental Monitoring and
Support Lab. (OMTS)
Industrial Environmental Research Lab.
(OEMI)
Municipal Environmental Research Lab.
(OALWU)
Health Effects Research Lab. (OHEE)
Environmental Research Information
Center (OMTS)
17 Grosse Ile, Michigan (OHEE)
18 Monticello, Minnesota (OHEE)
19 Duluth, Minnesota
Environmental Research Lab. (OHEE)
20 College, Alaska (OHEE)

Funding by Mechanism

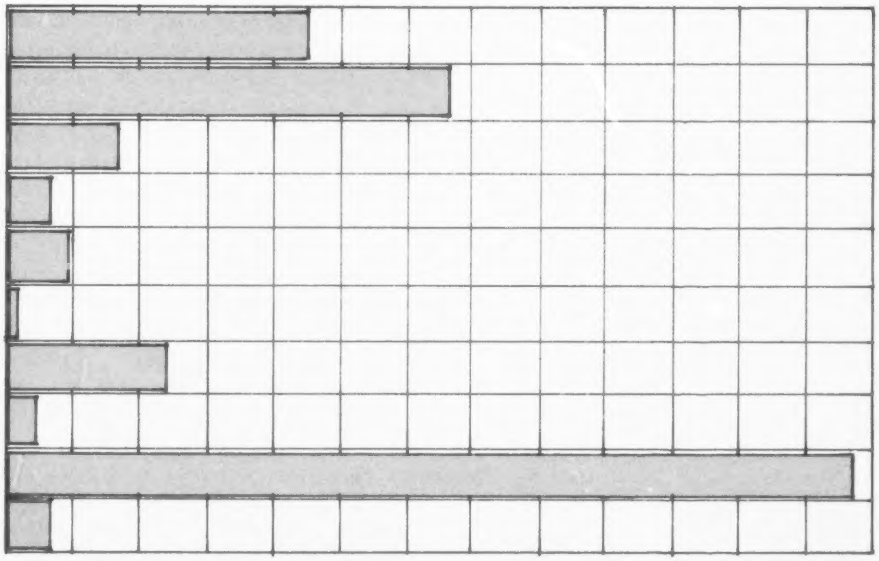


Funding by Program Category

	$M
Health Effects	29.6
Ecological Processes & Effects	19.9
Transport & Fate of Pollutants	12.1
Mineral Processing & Mfg.	12.3
Renewable Resources	5.5
Waste Management	28.0
Drinking Water	16.3
Environmental Management	1.4
Measurement Techniques & Equipment	3.3
Characterization & Measurement Methods	8.7
Quality Assurance	8.2
Technical Support	10.6
Energy Extraction & Processing	29.1
Energy Conservation Use & Assessment	62.8
Energy Health & Ecological Effects	36.3
Anticipatory Research	4.6
Other	6.9
	295.6

Funding by Media

	Positions	$M
Air	409	43.4
Water Quality	526	56.5
Drinking Water	115	16.3
Solid Waste	22	6.9
Pesticides	124	9.6
Radiation	30	.8
Interdisciplinary	338*	22.1
Toxic Substances	48	3.4
Energy	148	129.7
Program and Support	105	6.9



*Includes 105 reimbursable positions

Funding by Appropriation

	Positions	$M
Research and Development	1847*	295.2
Abatement and Control	18	.4
	1865	295.6

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in conclusion

ORD research will continue to supplement basic and applied environmental science

The research results described in this report have come from a cross-section of the nearly 2,500 projects under the direction of ORD. Some of the projects will continue next year, others have produced testing, monitoring, or analytic techniques that may find new applications in the future and still others have raised questions which may themselves become the subject of research. In all, however, we have designed the experiments, data collection, and presentation of results to serve specific missions ranging from direct support of EPA regulation and enforcement to basic research about the fundamental science of pollution processes.

Next year our research highlights are expected to cover a similar wide spectrum of results. We anticipate more results on the complex interrelationships of energy processes and the environment; projects designed to meet the mandates of the 1976 Resource Conservation and Recovery Act or the 1976 Toxic Substances Control Act will also produce more tangible results next year. Additionally, continuing analysis of pollution transport and transformation experiments will result in refinements in our understanding of population exposures to hazardous pollution. There may also be significant and interesting results concerning human vulnerabilities to low level, non-ionizing radiation from proliferating electronic devices. Finally, our water pollution research covering drinking water, watershed management, muncipal and industrial wastewaters will continue to build the data base of knowledge necessary for regulatory support.

Through this report and others like it, through seminars and technical articles in scientific journals, we will continue to disseminate our research results to the rest of EPA, other federal agencies, Congress, business and industry, state and local governments, the scientific community, and, most importantly, to the informed public.

☆ U.S. GOVERNMENT PRINTING OFFICE : 1979 O—289-225

the people

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